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A MONTHLY JOURNAL FOR ENGINEERS, ARCHITECTS, SURVEYORS & CONTRACTORS and all interested in CEMENT, CONCRETE, REINFORCED CONCRETE, FIRE-RESISTING CONSTRUCTION and STRUCTURAL STEEL.

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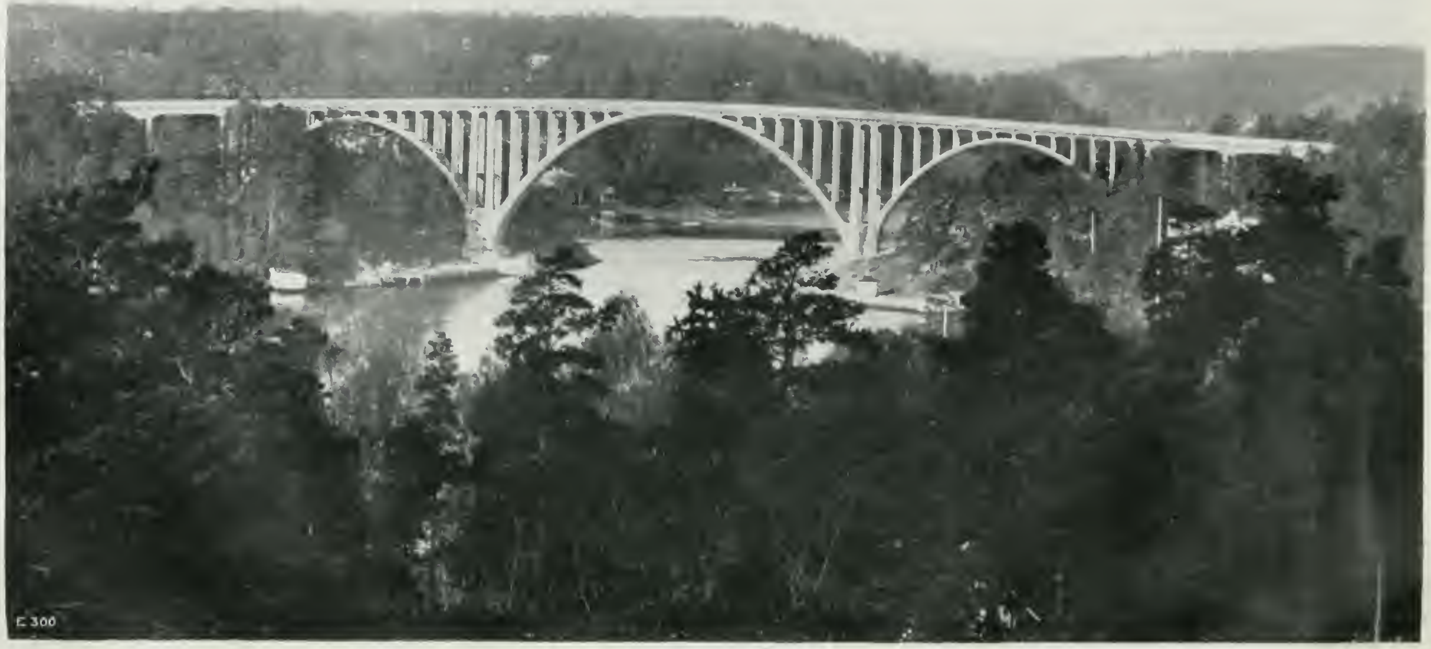

View of Finished Bridge.

Reinforced Concrete Bridge over the Skurusund, Sweden.

(For description see page 5.)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

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EDITORIAL NOTES.

THE ORGANISATION OF THE ENGINEERING INDUSTRY.—A PROPOSED SCHEME.

THERE is no doubt that it came as a great shock to many in Great Britain, after the war had been in progress for a short time, to find how extensively the trade of the world had been captured by Germany in the past, and many vows have been registered as to future conduct in trading with our enemies when the war is over. But it is essential for manufacturers in this country to seize the golden opportunity and endeavour to organise in such a manner that the custom of their fellow-countrymen is retained, and in addition to this they must strike further afield and recapture the trade in other parts of the world which was theirs in the past. The high standard of British workmanship has never been questioned, and the hall mark "British Made" should be the finest possible asset to our manufacturers; but it is not sufficient to stand on this alone and expect unlimited trade to follow. We must combine and go out into the world to fetch the business, and show other nations that we are no mean competitors In the past few years we have sadly neglected the foreign markets, and in consequence have been beaten on all points in the industrial world, and it is time that we threw off the semi-indifference under which we labour and realised our responsibilities as a leading nation. What applies to industry in general applies to the engineering industry in particular, and we welcome the efforts that are being made by the Engineers Club, Manchester, who have appointed a special committee to consider the whole question on a comprehensive basis. We have before us the Report of this Committee, submitting recommendations for organising British engineering industry, and these recommendations are certainly worthy of serious consideration. Some very sensible remarks are contained in the prefatory note, where it is stated that sacrifices of time, of some small measure of money, and a few concessions from the strongly marked individualism of our race will be required before we can gain the full benefit of our organisation, and with this we agree. Germany's success has been due to education, to co-operation and to organisation in manufacturing and selling backed up by adequate financial support. and we have been partly indifferent, very independent, and appear to have lacked any real support from the Government either financially or otherwise. New ideas have been rejected and sent out of the country, and no encouragement offered in the development of scientific research. In Germany the banks work in harmony with manufacturers, to the mutual advantage of both, but such a condition does not exist in this country. All these matters could be improved by the formation of a proper organisation which would be powerful enough to protect the interests of the engineering industry, which has behind it over 300 millions capital. The committee above mentioned recommend the formation of an association on a non-trading and non-interference-with-prices basis, with a constitution giving it a legal status framed on broad principles. Such an association would, it is claimed, speak with a powerful collective voice in matters with which Parliament was concerned, would assist the Government in questions connected with industry and commerce, and would be entitled to representation on the governing bodies of universities and technical colleges, and it would not trade in any way whatever, but assist all members equally in obtaining business and act in furthering the interests of the industry as a whole. The general management of the association should be in the hands of a thoroughly competent business man, of unimpeachable integrity, under the direction of a representative and periodically elected council, with headquarters in London or Manchester. In addition, it is proposed to elect standing committees in order to advise the council in regard to the following departments of the work: (1) general purposes; (2) intelligence; (3) production; (4) inventions and patents; (5) publicity; (6) finance; (7) education and research; (8) Parliamentary.

It is impossible to devote space to describe in detail the proposals as to the working and functions of these committees; but it may be said that they appear to have been well considered, and if carried out on the lines suggested. should prove very beneficial to the whole industry. In order to be a success, however, the organisation must be complete, and it must represent, not merely a small section of the more progressive manufacturers, but the whole industry, and it must be backed up by the Government. It is quite useless to hope for success in the foreign markets of the world unless these two conditions are complied with, and it is the duty of all concerned to co-operate in the matter and make the combination sufficiently powerful to demand proper recognition. The endeavours of the Engineers Club are a step in the right direction, and we offer our congratulations and promise our heartiest support to a movement that is framed to help that industry which is our especial interest.

THE CONCRETE INSTITUTE.

In our last issue an abstract was published from the Presidential Address given by Professor Henry Adams, M.Inst.C.E., on the occasion of the commencement of his second year of office, and there is much of interest in this address.

The President touched briefly on the work of the Institute, and expressed the opinion that the arrangement of the present committees is not quite the best that can be desired. This opinion is worthy of consideration and should be acted upon by the Council of the Institute.

There is no doubt that the Institute has done a certain amount of really good work since its foundation; but at the same time a great deal more remains to be done, and we feel that this should be realised by the Council and members generally, and greater efforts made in the future than in the past.

Without wishing to appear too critical we would like to say that one impression which we have formed with regard to the proceedings generally is that there is too much reserve among the members, and there is a tendency to hold back knowledge and experience which would prove valuable to designers and workers in reinforced concrete. The President appears to share this opinion, if one may judge correctly on reading a portion of the address, and we hope that the remark made by him that "the time has gone by when engineers are justified in regarding their knowledge of how to do things as professional secrets" will be seriously considered by those to whom it was addressed.

RESEARCH WORK.

Reinforced concrete is sufficiently new to offer a tremendous field for study and research work, and to keep the material in the front rank of building and engineering it is essential for all those proficient in it thoroughly to educate the masses and give them confidence to adopt what is a scientific material. There is no other body which can assist so much in this matter as the Concrete Institute, and if they will only realise that their duty lies in giving the very best possible information to all those interested in the subject they will achieve much.

The President suggested that the Science Committee should be more comprehensive and undertake the whole business relating to the principles of, and constructional practice in, reinforced concrete, with power to appoint sub-committees, such as Cement Tests Sub-Committee, Research Sub-Committee, and Failures Sub-Committee. With this we heartily agree, and certainly consider that the question of research work is one that must be dealt with by the Institute without further loss of time. The question of expense may be raised as a difficulty, but surely this would not be insurmountable. If a grant could not be obtained, there are, no doubt, sufficient prosperous members who would contribute towards the initial cost, and in time a great deal of work of a remunerative nature could be undertaken for architects and engineers who feel the need for an institution of this kind. We are very much behind with research work in this country and cannot hope to make rapid strides in reinforced concrete until this fault is remedied.

FAILURES.

The question of failure is another matter of importance, and is one that should be taken up boldly. Every failure that occurs is held up by the uninitiated as conclusive proof of the undesirability of using reinforced concrete, and yet, upon investigation, it will be found that every failure is brought about by preventable negligence or ignorance. The Institute should form a special committee whose duty it would be to investigate thoroughly the circumstances which were responsible for any failure, and a report should be prepared for circulation among the members of the Institute, who would then be able to speak with certain knowledge on each case, and at the same time benefit by the experience gained through such investigation. It is a true saying that we learn more from our failures than our successes, and this is especially applicable in the case of reinforced concrete.

GENERALLY.

The various sections of the subject upon which useful information might be given to the members are too numerous even to attempt a detailed description of them in these notes, and it would be impossible to deal with many of them immediately; but some kind of a general programme of work to be done should be drawn up by the Council on broad lines, and each committee should be steadily engaged on the portion of the programme allotted to it. The Institute in this way would become of the maximum benefit, not only to individual members, but to all those connected with the building industry, and its importance and power would increase in proportion to the amount of valuable work accomplished. The Institute cannot afford to stand still; and it has a great future if it will realise its possibilities as an institution formed for the purpose of dealing with a scientific method of construction which will become practically universal in a few years' time.

THE REINFORCED CONCRETE BRIDGE ACROSS THE SKURUSUND, SWEDEN.

By GEORG BROCKNER.

Quite a number of difficulties had to be overcome in connection with the design and erection of the bridge described below.—ED.

The Skurusund reinforced concrete bridge was opened by the King of Sweden on October 22nd, and will rank high amongst reinforced concrete structures. It was designed by Mr. Tor Kempe, C.E., and the Arcus Co., Stockholm, were the contractors.

A new bridge across the picturesque Skurusund, in the vicinity of Stockholm, connecting the mainland with the Värmdö island, having been decided upon, it was essential to make provision in the design for the ever-increasing shipping traffic which would pass under this bridge. The old floating bridge, of which a good many are still to be seen in different parts of Sweden, had about run its course, and also had many serious drawbacks. The new bridge was to be erected about 200 m. south of the old bridge, where the sound is narrowest (about 60 m.) and the shores consist of projecting rocks. The plans originally accepted by the authorities were for an iron structure and were designed to allow for a stationary bridge having a free height of 30 m. above high-water level and a free span across the sound of 60 m., with viaducts on either side of about 10 m. span.

Before tenders for the iron bridge had been invited, the Arcus Company, of Stockholm, submitted preliminary provisional plans for a reinforced concrete bridge, and by virtue of its æsthetic advantage and practically the absence of maintenance costs, a reinforced concrete structure was finally decided upon. The original offer stipulated for a bridge with a central span of 60 m. width and 32 m. height above water level, with two smaller arches adjoining of 30 m. span. The roadway across the bridge to be supported by pillars, the viaducts facing these latter consisting of beams on high trestles. As a second alternative it was proposed to substitute 15 m. free span arches for the trestles, but this latter scheme had to be abandoned on account of the increased cost.

Upon acceptance of the design, it was found desirable to make certain improvements on these original preliminary plans, and after some consideration and various suggestions the authorities decided on a central arch of 72 m. free span and 32 m. height, with side arches increased to 49 m. with a height of about 20 m., so as to coincide in shape with the central arch. Of the originally-proposed beam viaducts there now only remained 65 m. on the Skurn side and 35 m. on the Värmdö side, and through a removal of the land supports the length of the viaduct was further reduced. The span division of

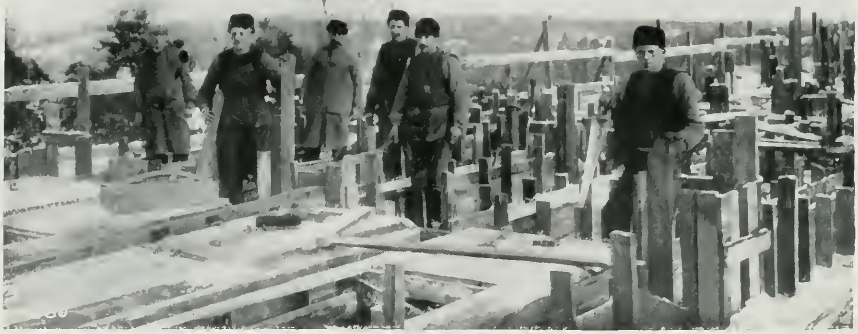
Fig. 1. Showing Moulds.

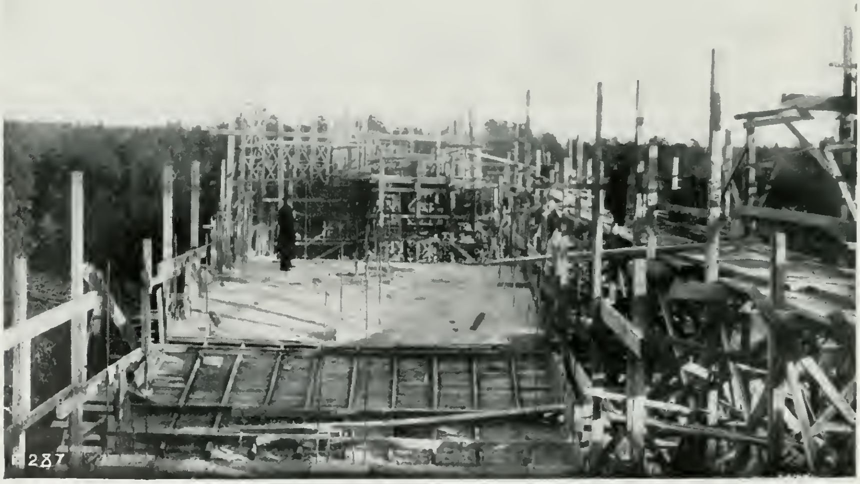

Fig. 2. Completion of One of Smaller Arches.

Reinforced Concrete Bridge over the Skurusund, Sweden.

the latter is not the most economical, but has been fixed with a view to appearances, and the same remark applies to the placing and the dimensions of the pillars, which are materially stronger than necessary. On the other hand, the arrangement of the pillars in groups of four was a natural outcome of the provision made for expansion. The roadway is so divided by cross-grooves that the beam viaducts are separated, and each arch with its roadway forms a separate system. Each of these systems is finished with stiff bracing, which conveys the wind pressure to the ground. The adjoining wind braces, between which the expansion grooves are to be found, constitute a pillar group. To make the arches more stable they have been broadened towards the springing. Brackets have been placed under the projecting gangways. To the pillars near the water have been attached smaller parapets. For appearance sake,

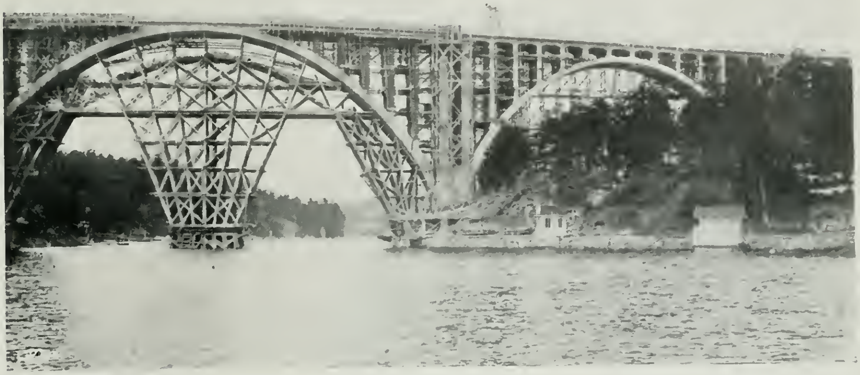

Fig. 3. View of Bridge from the South.

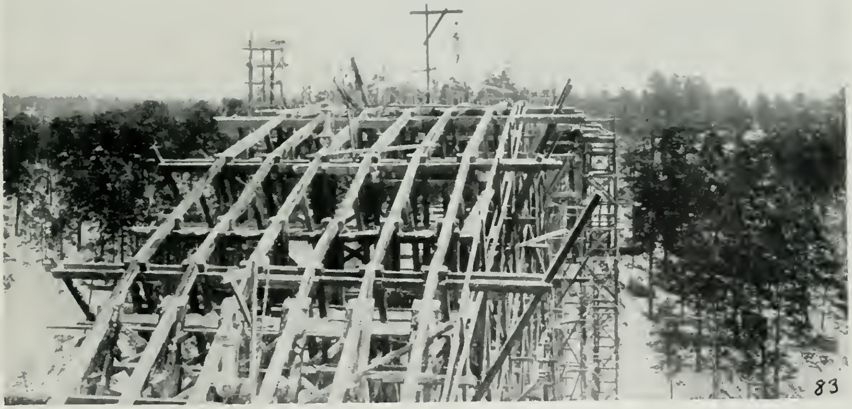

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Fig. 4. Showing Central Scaffolding.
Reinforced Concrete Bridge over the Skurusund, Sweden.

all the pillars are formed with an entasis. Otherwise the construction has not been altered from architectural considerations. Professor L. I. Wohlman, the well-known architect, has assisted in this connection.

The contract for the bridge was signed in April, 1914.

The breadth of the bridge-way is 7·5 m., of which 5 m. form the carriage roadway, with a footpath on each side of 1·25 m. The roadway of the bridge from the land side to the centre has a gradient of 1 : 30.

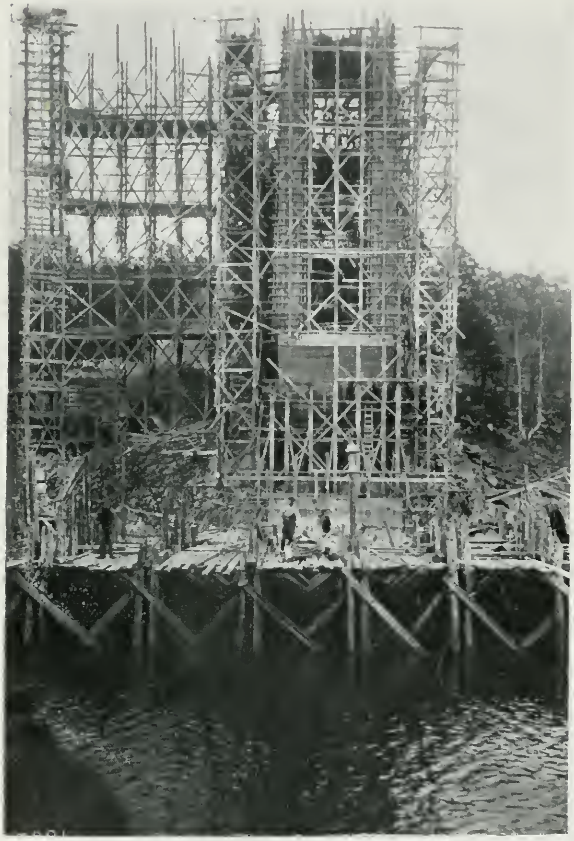


Fig. 5. Scaffolding Foundation.
Reinforced Concrete Bridge over the Skurusund, Sweden.

The calculations were based upon the following loads: (1) The weight of the finished bridge itself; (2) live load, foot traffic, 500 kg. per sq. m.; (3) live load for wheeled traffic, two rows of 5-ton waggons, a 10-tons goods motor-car, and four wheeled tramcars with 3 tons wheel pressure. The wind pressure was calculated at 250 kg. per sq. m. on the unloaded bridge and at 150 kg. per sq. m. on the loaded bridge.

When combining all the effects which could assert themselves in one place according to the above specified loads, the aggregate stress must not exceed for reinforcing iron in tension 800 kg. per sq. cm., adding wind and temperature stresses 1,000 kg. per sq. cm. Compression on concrete: mixture 1 : 2 : 3 40 kg. per sq. cm., 1 : 3 : 3 35 kg. per sq. cm., 1 : 5 : 7 10 kg. per sq. cm. Shear in concrete 1 : 2 : 3 or 1 : 3 : 3 must not exceed 4 kg. per sq. cm. Otherwise the conditions accepted by the Swedish Technological Union as regards reinforced concrete construction have been observed.

The roadway is supported by a reinforced concrete slab, 16 cm. thickness, resting upon five beams with 1·5 m. distance between them. In calculating beams and slabs, due regard has been paid to continuity, and the disposition of the reinforcement has been fixed with the aid of influence lines. The longitudinal beams are supported in the viaducts by strong frame constructions, which receive the wind pressures, and, in addition, are so designed that they can give with the expansion of the roadway. The longitudinal roadway beams are supported by trestles, with three pillars 3·9 m. apart, and the roadway is firmly connected with the top of the arches, and thus expands in both directions. The longer pillars on the arches, as well as the pillars of the wind frames, can, without excessive stress occurring, receive the bending stresses arising from this, but the shorter pillars have been constructed as pendulums with a simple chain construction upwards and downwards. All the pillars on the arches are the same breadth—viz., 0·55 m. As it was desirable to have the top of the central arch as high as possible, the roadway rests direct upon the arc at the crown without any intermediate layer.

The arches are of solid construction, as a comparative calculation showed that nothing would be gained by dividing them into a number of supporting ribs. In calculating the arches influence lines have not been used.

The side arches have a free span of 49 m. and a height of 20 m., and are 75 cm. thick at the crown and 6·7 m. broad, and at supports respectively 1·22 and 7·05 m. The arches are reinforced in both directions with four 13 mm. iron rods per metre breadth.

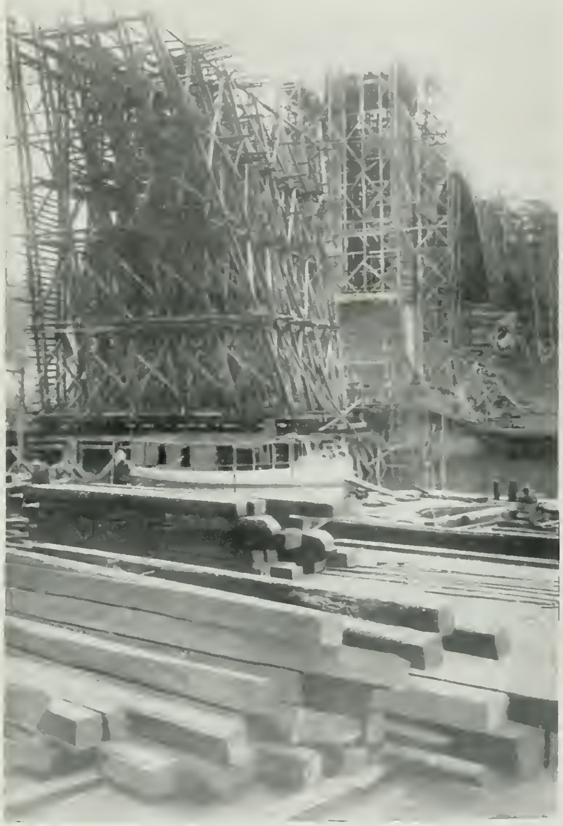


Fig. 6 Central Scaffolding.
REINFORCED CONCRETE BRIDGE OVER THE SKURUSUND, SWEDEN.

The large arch across the sound, with a 72 m. free span and about 28 m. height of pillars, is 1·05 m. thick at the crown and 6·7 m. broad, and at the support 1·8 m. thick and 7·15 m. broad. Although no reinforcement of the arch was actually needed, yet for safety's sake four 13 mm. iron rods have been inserted per metre breadth both on the upper and lower surfaces.

The roadway is insulated with asphalted felt. The insulation is protected by a layer of porous concrete, 8 cm. thick, on which rests the carriage-way, which is covered with tar-macadam. The footpath, which is covered with the same material, is separated from the carriage-way by granite kerbstones.

Extensive scaffolding was necessary for the casting, and especially the scaffolding for the arches had to be constructed with much care. As regards the side arches, the scaffolding offered no difficulties, inasmuch as the timbers could be placed direct on the rock or on cast plinths. As regards the central arch, it was first contemplated to build the scaffolding direct in the sound on piles, but, on closer examination of the ground below water, it was found that in most places the piles had to be fixed in the rock, which, however, had a considerable slope. This plan was therefore abandoned, and instead the scaffolding was arranged with one central support, from which the timbers were erected fan-shape. Support for the scaffolding was obtained on the shore by means of concrete plinths, which were placed as far out as possible.

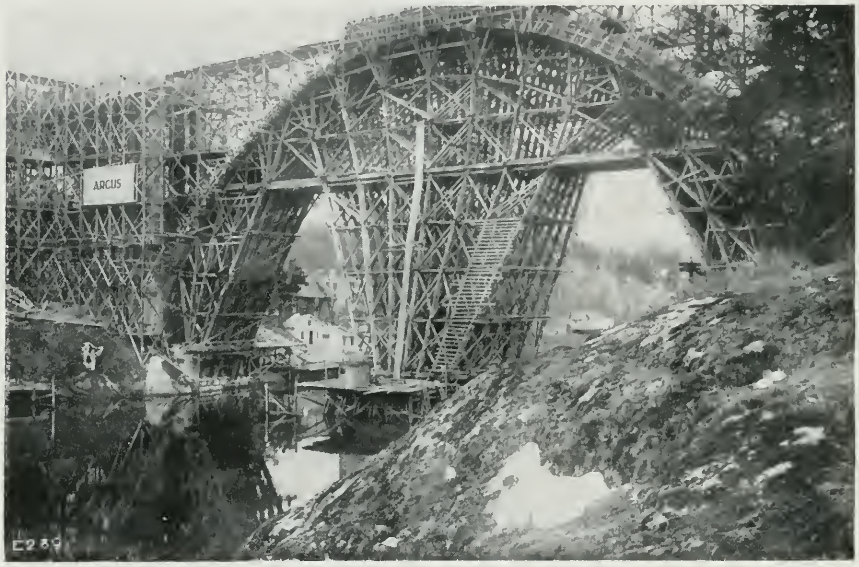


Fig. 7. Another View of Central Scaffolding.
Reinforced Concrete Bridge over the Skurusund, Sweden.

The depth of water in the middle of the sound was 8 m., and it was found that the soil at the bottom consisted of loose clay and gravel overlying the rock. As far as possible the loose clay was removed and replaced with gravel, and piles were then driven to the rock. These piles were cut off at the water level and the scaffolding and centering was erected on them with passage for shipping on either side.

As no surface treatment of the concrete was intended, all the centering had to be made with the greatest care, and the boards were placed according to a certain system, so that the unavoidable grooves could make a natural decoration of the large surfaces, which would otherwise have had a dead and dull appearance.

Swedish materials were used throughout for the work. There are about 5,400 cu. m. of concrete in the bridge, of which 3,700 cu. m. were reinforced.

Before the actual work could be put in hand extensive preparations were necessary on both sides of the sound, such as arrangements for conveyance and discharge of materials, which was all done by means of lighters and derricks. The steepness of the shore further necessitated separate transport railways to the respective depôts, for which purpose Decouville lines were used, up which the wagons were drawn by means of motor-worked winches at the top end of the lines. For mixing the concrete, a good-sized mixer was installed on either side of the sound, each having a hoist with automatic tip shovels. The mixers and the hoist were worked by the same motor.

Notwithstanding the low percentage of salt in the water of the sound, it was not considered advisable to use this water for the concrete mixing, and a water-pipe was installed from a pond at Stord Björ Knäs, with a pipe under the water of the sound to the other shore. As the pond in question is only situated 25 m. above the sound, and the greatest height to which it should be raised was 35 m., a pump with motor had to be coupled to the pipe line. During the building it has thus been necessary to use no less than seven different motors, worked with raw oil or petroleum.

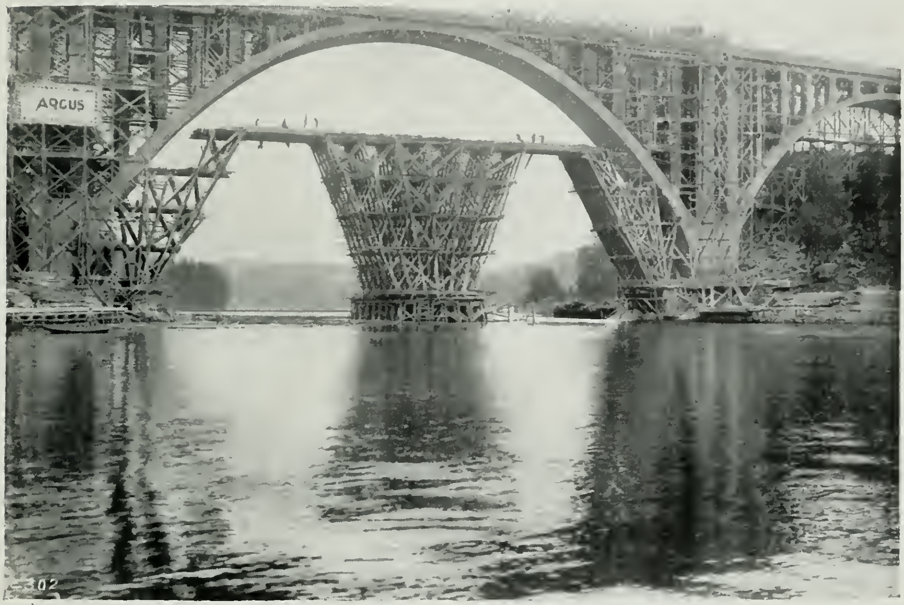


Fig. 8. Removal of Central Scaffolding.
Reinforced Concrete Bridge over the Skurusund, Sweden.

The work was commenced in April, 1914, with the construction of quays and rock blasting for the intermediate pillars for the beam viaducts. During the summer and the autumn the viaducts, the side arches, and the pillars nearest the sound were cast, and during the winter the large central scaffolding with moulds for the arch and moulds for pillars and roadway on the side arches could be proceeded with.

The casting of the large arch was commenced April 26th, 1915, and the last groove at the top was cast May 20th, after which the work with moulds for pillars and roadway was commenced. At the same time the casting of the upper structure of the side arches had been going on. When the arch scaffolding beneath the large arch had been lowered by means of screw-jacks—which was done towards the end of June—the pillars and the roadway of the same were cast. All the supporting structures were completed by the middle of July. The bridge was finally tested in September last with a load of 600 kg. per sq. m., as per contract. No perceptible deflection was observed.

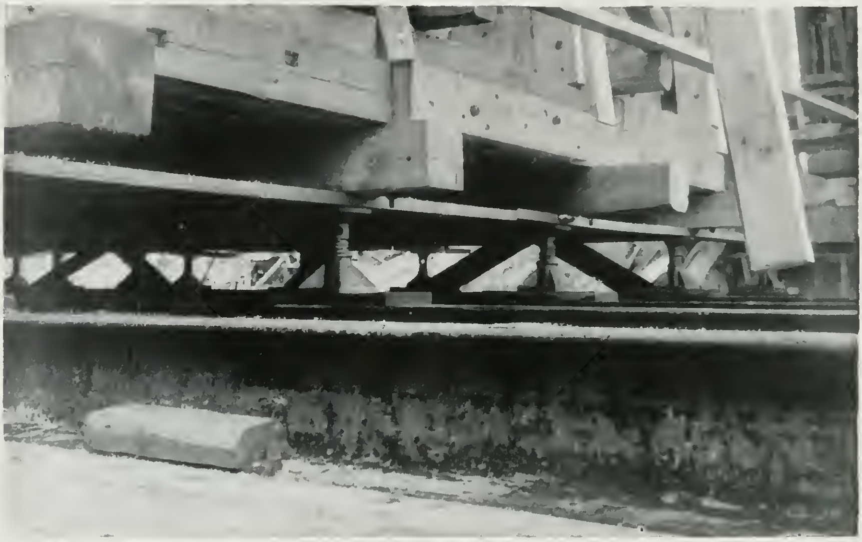


Fig. 9. Screw Jacks under Central Scaffolding prior to loading.

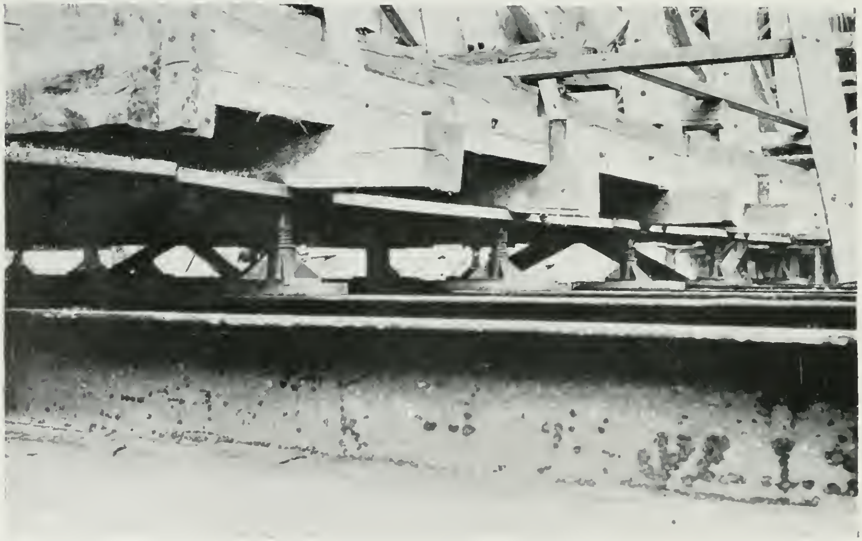


Fig. 10. Screw Jacks under Central Scaffolding after loading.
Reinforced Concrete Bridge over the Skurusund, Sweden.

RECENT BRITISH PATENTS RELATING TO CONCRETE.

We propose to present at intervals particulars of British Patents issued in connection with concrete and reinforced concrete. The last article appeared in our issue of October, 1915.—ED.

Concrete Reinforcement.—*No.* 5,651/15. *Moritz Kahn, Caxton House, Westminster, London. Accepted September* 9/15.—According to this invention a reinforcing fabric is formed of a number of independent, relatively stiff, longitudinal bars, and a number of relatively flexible transverse bars intersecting each other, integral interlocking means being provided at the joints.

In the arrangement shown in *Figs.* 2-4 the main bars, *a*, have U-shaped slots, *b*, or holes, *e*, into or through which the transverse bars, *c*, are passed, the latter being provided with kinks or deformations. *h*. The bars are then locked together either by cutting two tongues, *d*, from the sides of the slots or by deforming the holes, *e*.

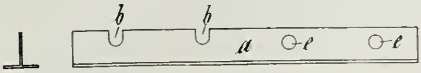


Fig 2.

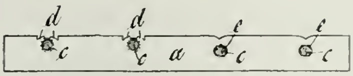


Fig 3.

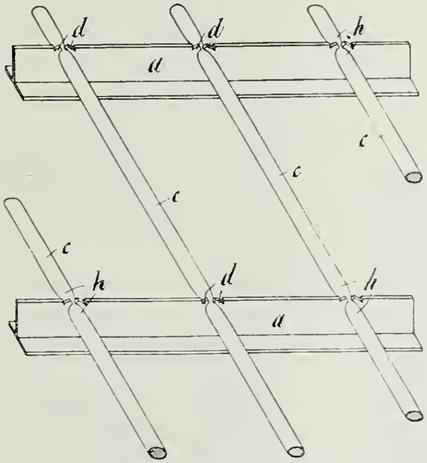


Fig 4

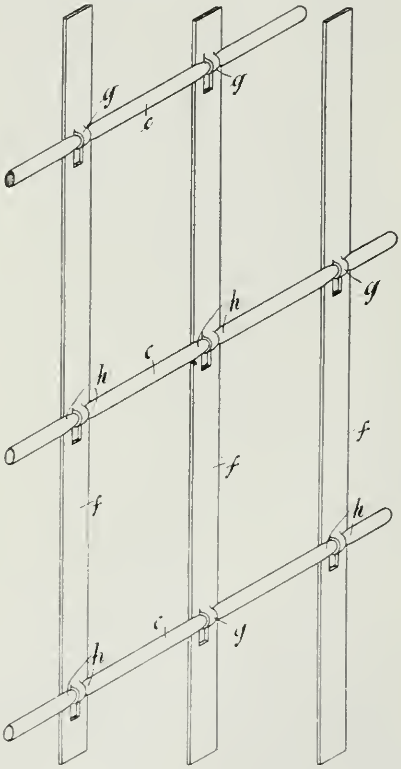


Fig 5

In the alternative arrangement shown in *Fig.* 5 bars of rectangular section are pierced to form tongues, *g*, which are then closed around the kinked bars, *c*, after they have been placed in position.

Concrete Walls.—*No.* 15,910/14. *T. W. Bailey, 29, Clarendon Avenue, Leamington. Accepted July* 5/15.—This is an invention for improved formwork for use in casting concrete walls *in situ*, and comprises scaffold frames, which support the moulding boxes so that they may be moved longitudinally without moving the frames, and can also be elevated without difficulty.

The scaffold frames, *A*, *Fig.* 1, are formed in one construction of T-bars with suitable bracing and carry at the top overhanging arms, *M*, by which the elevating gear for the moulding boxes is carried. Eye-bolts are carried by the frame near the top and bottom to receive the ends of angle struts, *N*, for bracing a pair of the frames

Fig. 1.

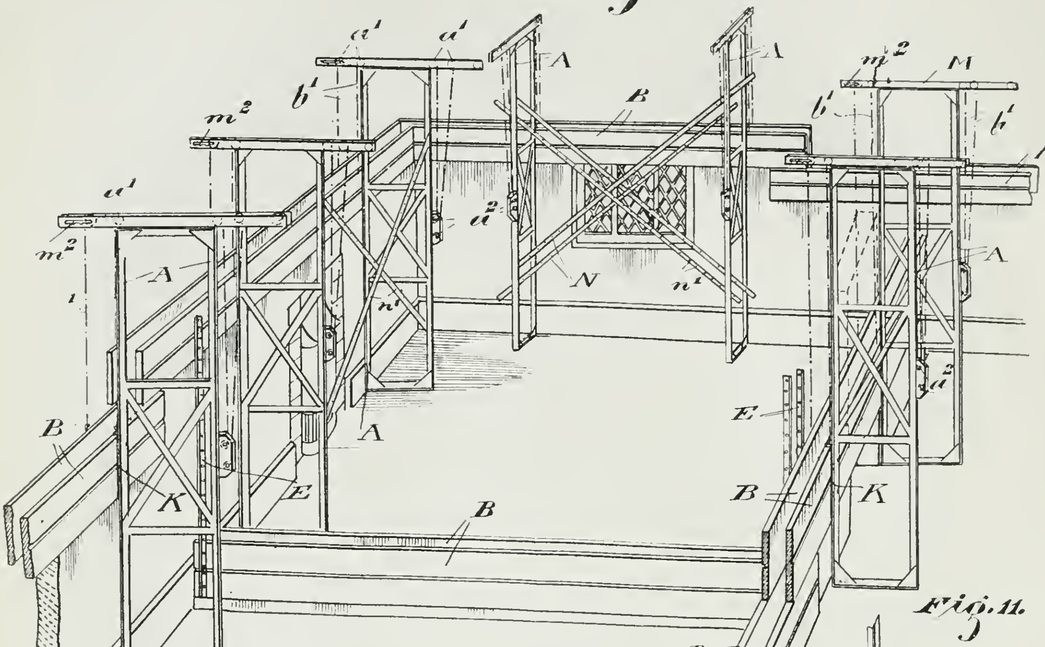


Fig. 11.

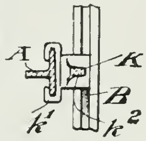


Fig. 10.

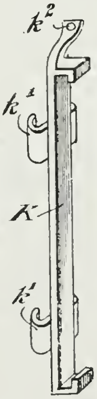


Fig. 15.

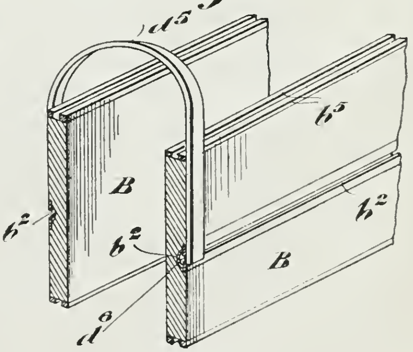


Fig. 6.

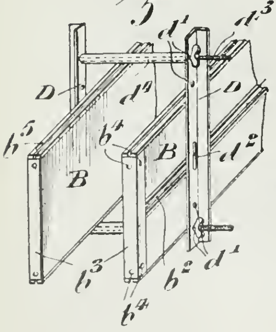
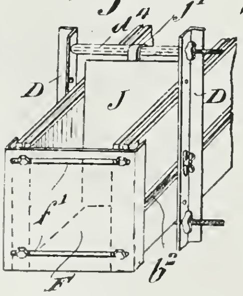


Fig. 7.



at convenient distance apart, the angle bars being provided with a number of holes to enable such distance to be varied. In a modified construction the frames are formed of channel or U-section, provided with an undercut slot, by means of which the moulding boxes, *B*, may be secured to the frames.

With the T-bar type of frame, holders, *K*, *Figs.* 10, 11, are provided; clips, k^1, embrace the T-bars, and an eye, k^2, is provided for attachment to the elevating gear. The holders are provided with ledges which engage grooves in the top and bottom of the moulding boards forming the boxes, *B*, as shown in *Fig.* 11.

The boards, *B*, carry angle bars, b^3, *Fig.* 6, at their ends, which may be closed by slotted plates, *F*, *Fig.* 7, by means of studs passing into holes in the angle bars, b^3. For adjusting the distance apart of the boards to deal with walls of different thicknesses a pair of angle bars, *D*, *Fig.* 6, are provided with holes, d^1, at top and bottom, and an elongated slot, d^2, at the centre. The top and bottom holes take a threaded rod, d^3, passing through a tube, d^4, acting as a distance piece, and the central slots take a bolt whose head is held in an undercut groove, b^2, running along the board.

A partition plate, *J*, may be suspended from the upper distance piece, d^4.

In a modified construction which does not interfere with the filling of the concrete, inverted U-shaped bars, d^5, *Fig.* 15, whose arms are bent to the requisite distance apart and have projections, d^6, which engage the longitudinal grooves in the boards.

In order to provide an effective vertical joint between successive portions of the wall, projections are preferably provided upon the end members of the boxes, so as to leave a dovetailed groove in the ends of the blocks.

Vertical angle bars, *E*, may be provided with holes at regular intervals and be utilised to hold the mould boards in rigid position at the junction between one wall and another, bolts passing through the holes in the channels engaging the grooves, b^2, in the boards.

Supporting Fittings from Reinforced Concrete.—*No.* 29,749/13. *Anders Jordahl*, 103a, *Potsdamerstrasse, Berlin. Accepted July 22/15.*—This invention comprises an improved method of supporting brackets, plummer-blocks, and other fittings on reinforced concrete ceilings, beams, or walls by means of an undercut channel section bar embedded in the concrete, bolts being supported by the channel bar, by means of which the fittings are secured.

The characteristic features of the invention are that the bar, 1, is formed with vertical ribs, 4, and that it is adapted to be secured to bars embedded in the body of the concrete.

Fig. 1

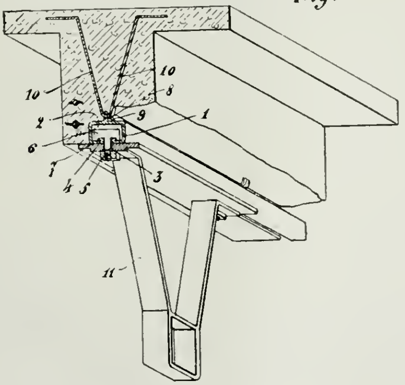
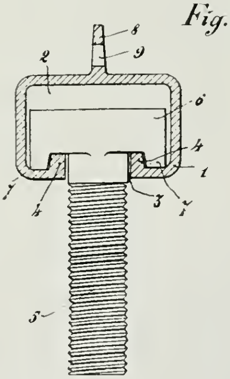


Fig. 2



The hollow space, 2, receives the heads, 6, of bolts, the stems, 5, of which project through a slot, 3, which may run from end to end of the bar. The bolt-heads have projections, 7, which prevent their rotation until they are lifted clear of ribs, 4, on the bars. The upper portion of the bar, 1, is formed with an upstanding rib, 8, in which apertures, 9, are formed to receive bars, 10, that are embedded in the body of the concrete.

Sheet metal caps are preferably provided at the end of the bars, 1, to prevent the concrete from getting into the channels.

Hollow Reinforced Concrete Floors—No. 1,642/15. *Frank Willis, 3, Milton Road, East Sheen, Surrey. Accepted August* 19/15.—This invention consists in an improved hollow floor having specially shaped beams made of reinforced concrete, special steel stirrups being employed for spacing the reinforcement.

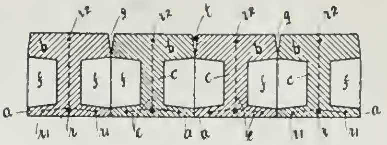


Fig. 1

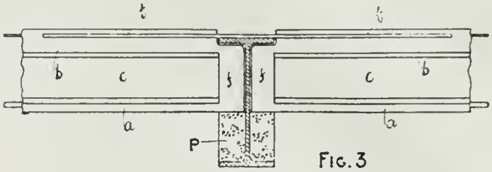


Fig. 3

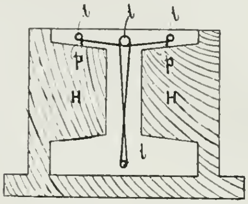
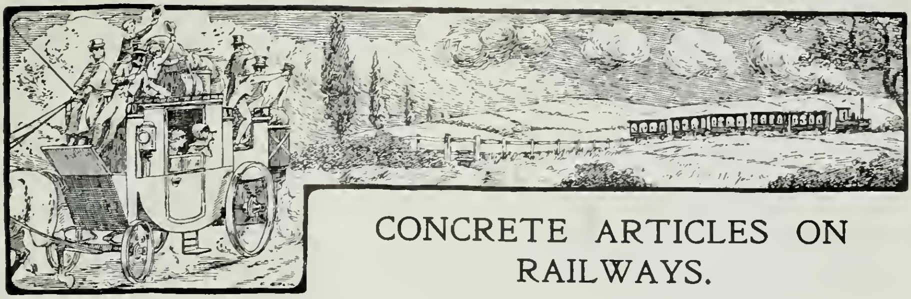


Fig. 4

The beam consists of a thin bottom flange, *a*, a thicker top flange, *b*, a web, *c*, brackets, *f*, reinforcement rods, *r*, r^1, r^2, and stirrups, *e*, the bottom flange being provided to form a flat under surface to the beam, and the brackets, *f*, being placed at each end of the beam to give additional strength to carry the reactions.

The wire stirrups, *e*, are bent to the shape shown in *Fig.* 4, and have loops, *l*, of varying sizes, through which the rods are passed and held at their requisite distance apart from each other; the ends of the wires so bent are extended to form projecting pieces, *p*, which rest upon the cores, *H*, of the mould, and so retain the stirrup, and thus the reinforcement, in the correct position during the pouring of the concrete.

V-shaped spaces, *g*, are formed at the junctions of the top flanges, and are subsequently filled with liquid cement, which forms the beams into a continuous slab, and where it is desired to obtain continuity of beams over a support reinforcement, *t*, may be provided in the grooves to carry the reverse bending moment.



CONCRETE ARTICLES ON RAILWAYS.

We have from time to time drawn attention to the great utility of concrete for railway work of every description, and in the following article it is intended to show how the use of this material has developed of late years on many of our railways. The pioneer work which has been carried out by some of our railway engineers may probably encourage others to similar enterprise. To those who are not acquainted with the methods adopted for making the many articles referred to we recommend a perusal of the book entitled "Everyday Uses of Portland Cement," published by the Associated Portland Cement Manufacturers (1900) Ld., which contains the fullest details as to moulds, methods of mixing the concrete, etc.—ED.

THE GREAT WESTERN RAILWAY.

A SUBJECT of considerable interest is the steady advance which some of our great railways have during the past few years made in the adoption of concrete articles, reinforced and otherwise, on the stations and along the line. In this respect the place of honour must undoubtedly be given to the Great Western Railway, to whose enterprise and initiative it is unnecessary to refer

Certainly some time has now elapsed since this Company began operations in the manufacture of platform paving slabs, these being the first things attempted at their Taunton depot. Each year, however, there has been an ever-increasing development of plant, machinery, and variety of output almost of a phenomenal character, and a fair conception of this will be gathered when we state that where originally there was one working shed on about a quarter of an acre of ground, the present concrete depot, storage yard, etc., occupies a space of nearly five acres. The following illustration affords a general view of the depot as it now exists.

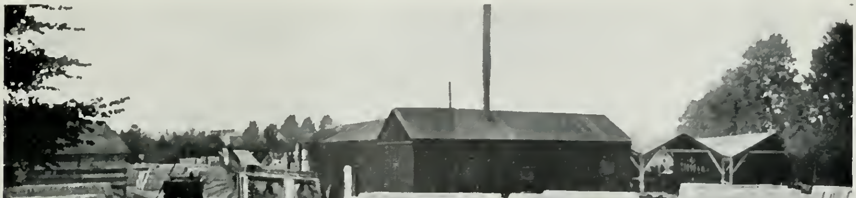


Fig. 1. General View of the Depot.
CONCRETE ARTICLES ON RAILWAYS.

During the first year platform slabs were made to an extent of 6,000 ft., and platform copings 273 ft. In 1914, taking these two articles by way of comparison, of the first named 109,000 ft. were produced, the size being 3 ft. by 2 ft. as a standard, 2¼ in. thick, and of the copings 12,000 ft. It can thus be easily understood how vast has been the evolution and increased production of concrete articles necessary to building constructions and the general requirements of the line. The list of things now being made is long and varied, but will be read with interest. It embraces :—

Platform paving.
Platform copings.
Platform framing sills and blocks.
Platform channelling.
Blocks for building.
Fence posts for paled and wire fencing.
Straining posts.
Gate posts.
Posts for level crossing notice plates.
Lamp-post bases.
Pipes, various sizes.
Culvert blocks.
Steps.
Window sills and heads.
Wall coping blocks.
Plinth blocks.
Cant blocks.
Gas syphon covers.
Inspection chambers.
Doorway channels, grating and outlets.
Concrete piles.
Gully-dish covers with 9 by 9 gratings.
Cattle drinking troughs.
Drainage pits.

With regard to the fencing posts, which are reinforced, it was in 1910 that these were first made, and during that year 543 were finished, enough to cover a distance of about two-thirds of a mile. Now 40,000 are produced annually, which is equal to 45 miles, and the subjoined photograph shows their admirable appearance, whilst their durability is practically without limit.

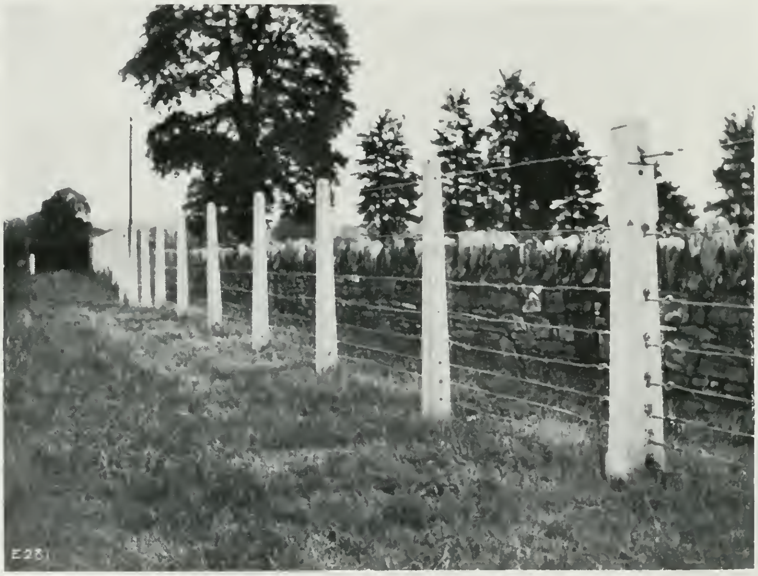


Fig. 2. View of Fence Posts.
Concrete Articles on Railways.

Platform fence-posts, reinforced, are well worthy of attention, as they give a good foundation for the wood paled fence on station platforms. They are, of course, free from decay, and that at least doubles the life of the wood portion, and, being framed as shown, any length of the timber can be readily removed by taking out two bolts.

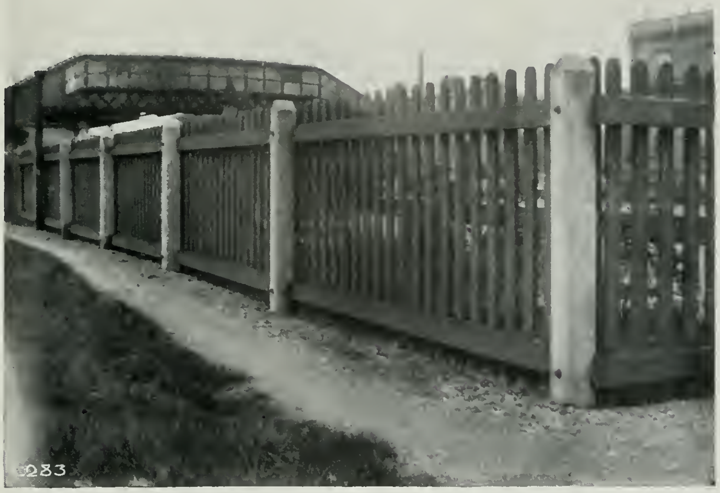


Fig. 3. Platform Fencing Posts.
Concrete Articles on Railways.

Concrete pipes form quite a remarkable feature of this company's industry. They are made in five different sizes, ranging from 18 in. in diameter to 3 ft. 6 in., and a length of 500 ft. of each size is always kept in stock.

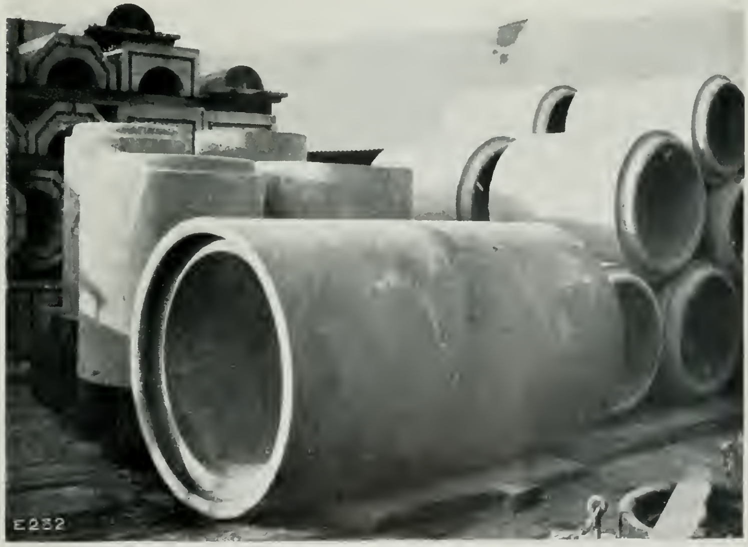


Fig. 4. Concrete Pipes.
Concrete Articles on Railways.

The Culverts.—These are well adapted for laying under railway banks or for taking the place of defective pipes where it is not desirable to use green concrete.

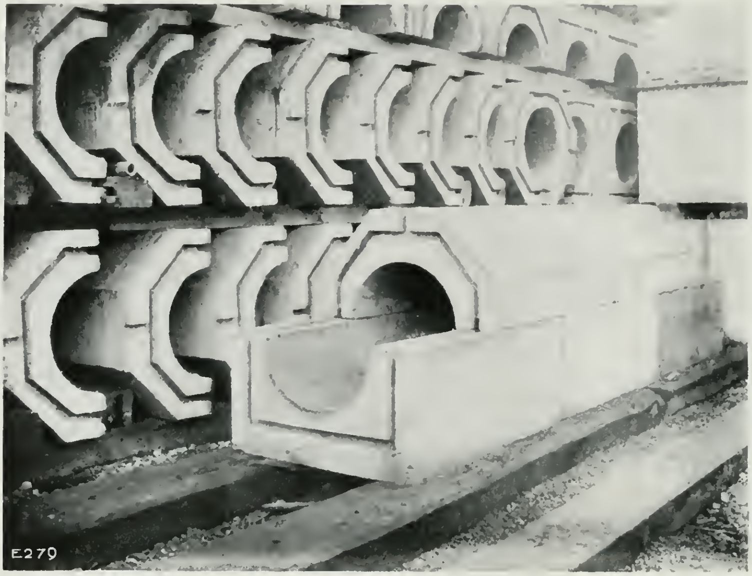


Fig. 5. View of Culverts.
Concrete Articles on Railways.

Concrete inspection chambers are made in slabs of 12 in. in depth, $4\frac{1}{2}$ in. thick, and in various lengths, so that chambers of almost any size can easily

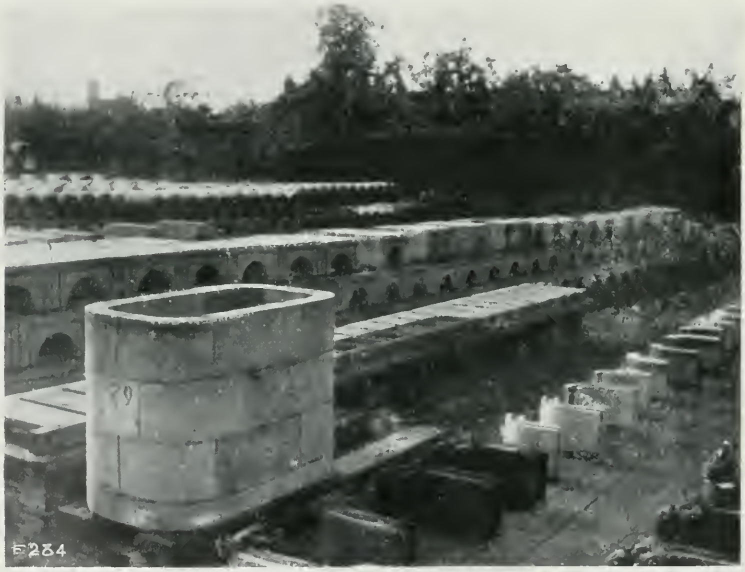


Fig. 6. View of Inspection Chambers.
Concrete Articles on Railways.

be fitted up from well-seasoned slabs kept in stock. The chambers are most suitable for use in bad ground, where brickwork would be pushed out of shape before the mortar had time to set.

The concrete drinking troughs are reinforced, and have only recently been made. The illustration gives an excellent example of their description.

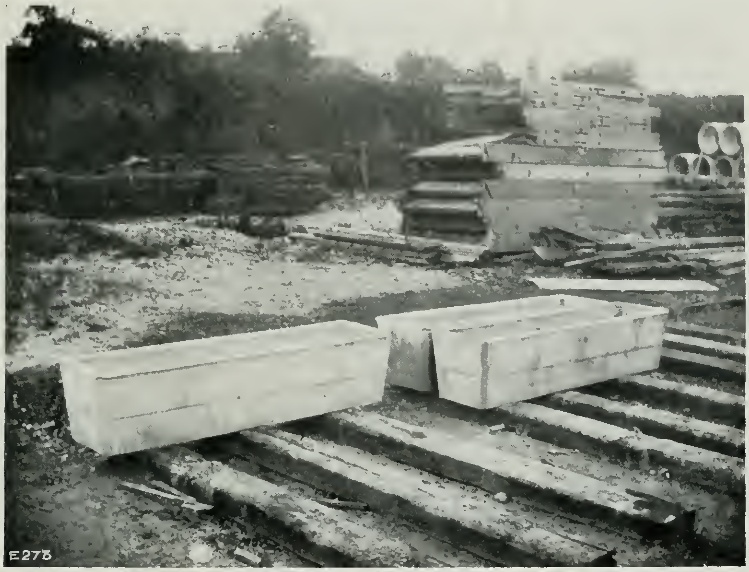


Fig. 7. View of Drinking Troughs.
Concrete Articles on Railways.

The moulds which are used for the production of the many articles alluded to are made at this depot. They combine all that is essential for the rapidity of manipulation and the turning out of highly finished work, of which it would be impossible to see better.

The aggregate in general use is limestone graded from $\frac{1}{16}$ to $\frac{1}{2}$ in., any deficiency of fine material being made up by the addition of washed Barnstaple river sand. Then is added a proportion of best Portland cement, J. B. White Bros.' brand, suitable for the article being made.

At this juncture it is not out of place to refer to the very thorough and careful system of tests to which all the productions of the depot are subjected, both as regards compression and resistance to tensile strain. A few examples will be sufficient to show that none of them are taken into actual use until they have been proved reliable and trustworthy. As instancing this, take the fencing posts. These are fixed to a ground level between beams from which 4 ft. 6 in. of the post projects. At 3 in. from the extreme end it is loaded, and a 5 in. by 5 in. post at ground level shows first sign of fracture at not less than 196 lbs., equal to 476 lbs. on each square inch of concrete.

In dealing with pipes, one, say of 30 inches, is tested with compression to the extent of 45 tons, which it has to resist without fracture.

Culvert blocks are tried in much the same way as the pipes, viz., by being loaded, but in addition a further compressive test is made of the strength of the grouted joint, which has to bear two tons on 4 ft. span, as shown below.

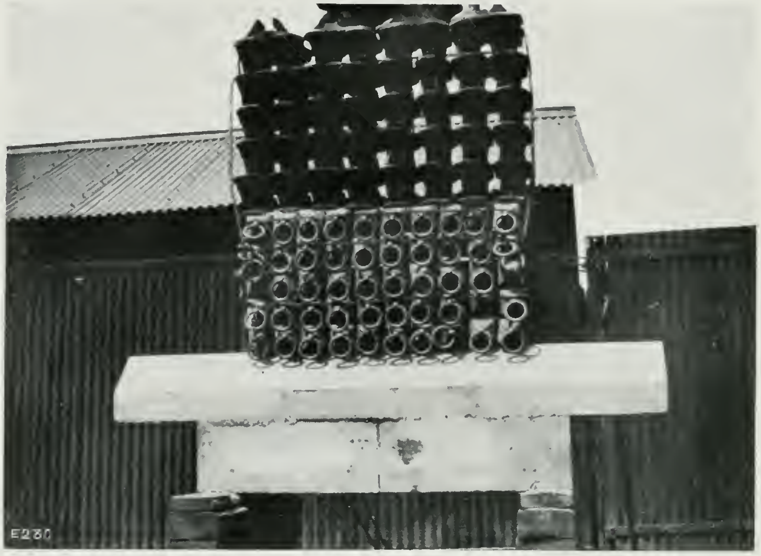


Fig. 8. A 2-ton Test on a Culvert Block.

Concrete Articles on Railways.

In conclusion we must thank the Great Western Railway for their courtesy in giving us an insight into their work at the depot, and especially the Divisional Engineer and his Inspector of Mechanics, who manage this department, for the information placed at our disposal. The Company may well be proud of their Concrete Works. Nothing is left to chance, and time has proved that what is well done is worthy of repetition.

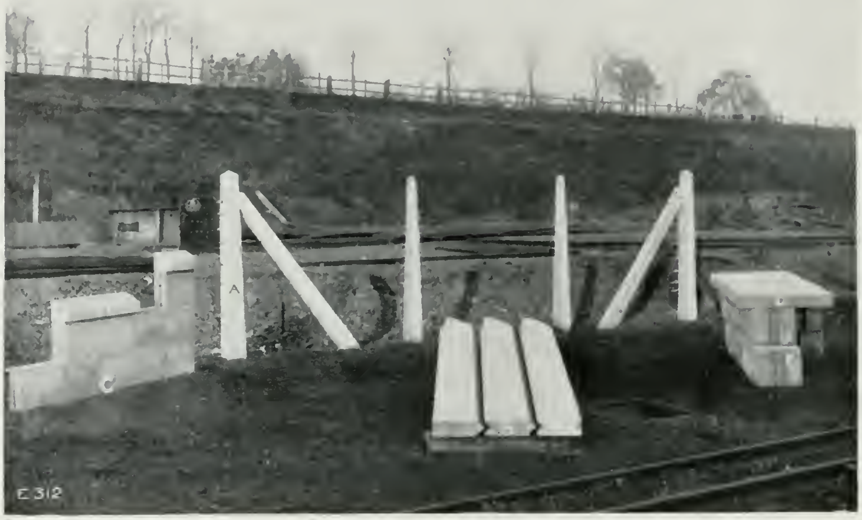
THE LONDON & SOUTH WESTERN RAILWAY.

It is only about three years since this Company seriously commenced making concrete articles for use in connection with the requirements of its line and general building developments inseparable to a railway. Even in this comparatively short period fairly rapid progress has been made, not only in the way of increasing output, but still further in its varied character. What the London and South Western Railway takes in hand it does thoroughly, and there is no doubt that but for the war and its attendant dislocation of most industries the advance in their concrete work would have been considerably augmented.

The depot at Exeter, which is under the direction and personal supervision of the Divisional Engineer, is situated on a well-chosen site, which in the first place lent itself to the construction of a convenient siding and loading-dock accommodation, and also possessed a sufficient area of level ground adjoining for stacking purposes, etc. Here a moulding shed, about 200 ft. in length by 28 ft. wide, has been erected, with spacious cement shed attached. To facilitate the transport of materials a small system of narrow gauge tramways has been laid down, affording connection between the moulding shed, storage ground, and the loading dock.

The various articles so far produced at this depot are platform paving and coping slabs, building blocks $4\frac{1}{2}$ in. in thickness, plinth blocks, and fencing posts; but, in addition, there are other things on a larger scale to which we shall presently refer. It is, however, in regard to the manufacture of the reinforced fencing posts that the executive has for some time chiefly devoted its attention, and it will not be out of place here to give some idea of the method adopted. The moulds are laid in frames of seven, the sides being made of well-seasoned timber with bevelled iron fillets screwed to the corners to form the chamfer on the edges of the post, and cast-iron moulded blocks to shape the rounded and mitred tops. Round iron rods pass through the moulds in the required positions to form the holes for the fence wire to pass through. The various parts of the moulds are all movable, and as far as possible interchangeable. The reinforcement consists of four steel rods of $\frac{5}{16}$ in. or $\frac{1}{2}$ in. in diameter, according to the size of the post. These, when accurately wired together to proper gauge, are suspended longitudinally in the mould, which is first well dressed with a special oil or grease, and is ready to receive the concrete. The aggregate of this is composed of two and a half parts of $\frac{1}{2}$-in. Meldon Quarry screenings, one and a half parts of Fremington tidal river sand, and one part of slow-setting Portland cement, J. B. White Bros.' The whole is thoroughly well mixed and sufficient water added to give a consistency which admits of its being well worked into the mould with small trowels. In about thirty-six hours the posts are released from the moulds; they are then stacked in the open to dry and season, and two months later are ready for use. The fence posts made in the manner described consist of straining posts with struts and intermediate posts. The former are 8 ft. in length, tapering from $7\frac{3}{4}$ in. by 5 in. at the ground line to $5\frac{1}{2}$ in. by 4 in. at the top, with an enlarged base or foot, $16\frac{1}{2}$ in. by 5 in. The struts are 7 ft. 8 in. in length, 5 in. by 4 in. at the top, 6 in. by 4 in. at ground line and 12 in. by 4 in. at base; the intermediate posts 7 ft. 2 in. long, $2\frac{7}{8}$ in. square at the top and 6 in. by 5 in. at the base.

It is anticipated that an output of not less than 500 per week will be reached in due course. The following photograph illustrates some of the articles referred to.



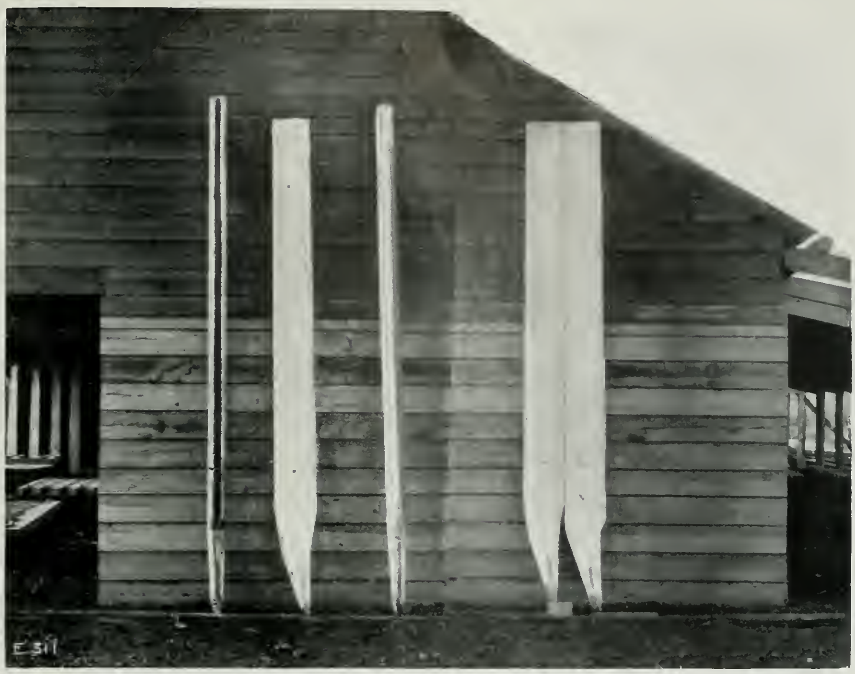
Concrete Works, Exmouth Junction, L. & S. W. Rly.

A. Reinforced Concrete Fence Posts.
B. Reinforced Concrete Piles.
C. Concrete Partition Slabs.
D. Concrete Platform Coping.
E. Concrete Plinth Blocks.
F. Concrete Walling Block.

Concrete Articles on Railways.

Turning now to other concrete matters, it is of interest to state that all the blocks forming the face of a dock wall extension were made at this depot. They numbered over 1,200 and each had a cubical capacity of about ½ cu. yd. These blocks were divided into an equal number of headers and stretchers, and were so constructed that the tapering sides of the headers corresponded with the splayed ends of the stretchers, and, consequently, interlocked one with the other when laid alternately in position in the wall. A large proportion of the blocks had to be provided with special features in the shape of weep holes, holes for fixing fender timbers on the face of the wall, etc. Separate wooden moulds were used, and the ingredients of the concrete consisted of three parts of Melton Quarry broken stone, two parts of ½-in. screenings, one part of ¼-in. screenings, and one part of Portland cement—no reinforcement being used.

Another item may well be mentioned, the reinforced concrete sheeting piles now in hand for strengthening the foundations of the river bridge at Barnstaple. These piles, which are 12 ft. in length by 11 in. by 4 in., are made of the same materials and in similar proportions as the fence posts. They are, however, reinforced with six ½-in. steel rods, and provided with a pointed iron shoe at the bottom to enable them to be driven into the bed of the river. They are likewise made with grooved and tongued edges. All these details call for special and somewhat intricate treatment in the matter of mould construction.



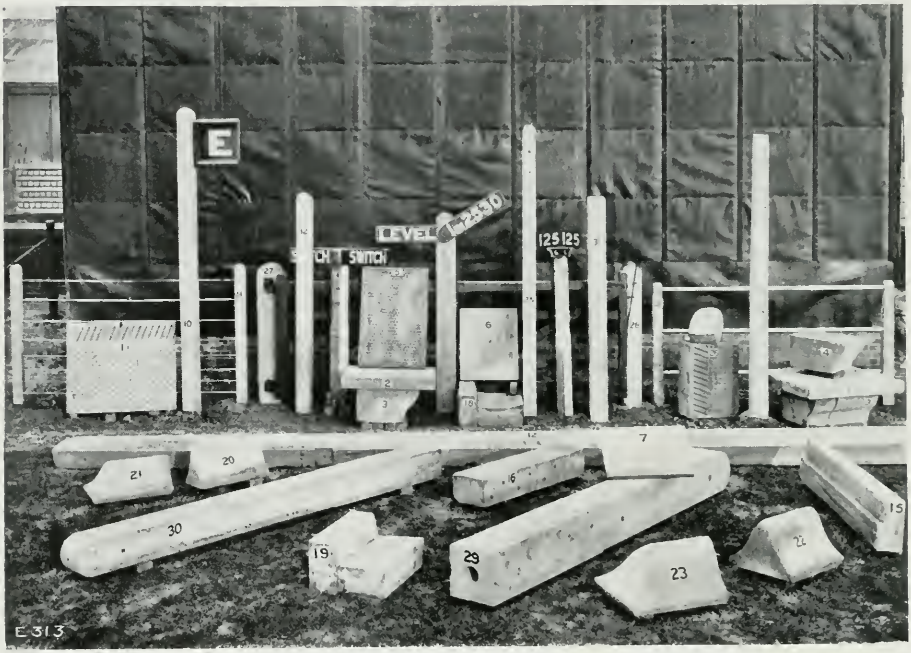
Reinforced Concrete Sheeting Piles for Barnstaple Bridge.
CONCRETE ARTICLES ON RAILWAYS.

As intimated in the earlier part of this notice the abnormal times we are experiencing has, of course, handicapped the work to no small extent; but enough has been done, and is continuing, to show the advantages, economic and otherwise, of a concrete depot on a railway.

BEYOND the details of work being done by the two companies above mentioned, it is interesting to record that other important railways have during recent years freely adopted concrete articles similar to those referred to, and with complete success. A noticeable example of this is given in the appended illustration, and the numbers on each correspond with the tabulated description.

1. Platform Coping.
2. ,, ,,
3. Oversailing for Platforms.
4. ,, ,, ramps.
5. Concrete Slab.
6. Paving ,,
7. ,, ,,
8. Wire Fence Post.
9. Platform Fence Post.
10. Station Name Board Post.
11. Gradient Post.
12. Display Board Post (special length).
13. Mile Post.
14. Buffer Stop Lamp Post.
15. Footbridge Step, with recess for special tread.
16. Leg or Bearer for Bed Timbers for Signal Box Connections.

17. Blocks for W.C. Pans.
18. Kerbing with channel.
19. ,, ,, ,,
20. Coping for 9-in. wall.
21. End Coping for 9-in. wall.
22. Coping for 14-in. wall.
23. End Coping for 14-in. wall.
24. Switch Post.
25. Notice Post.
26. Canal Wall Coping.
27. Hanging Post for 12-in. Occupation Gate.
28. Striking Post for ditto.
29. Hanging Post for 15-in. Station Entrance Gate.
30. Striking Post for ditto.
31. Hanging Post for Handgate.
32. Striking Post for ditto.



Concrete Articles on other Railways.

Platform Coping Nos. 1 and 2.—Are similar to the usual paving slabs on platforms, except that they have small holes in the top, which are left to be filled in with dirt and grit, and this tends to render the slab less slippery—a great advantage at the edge of the platform.

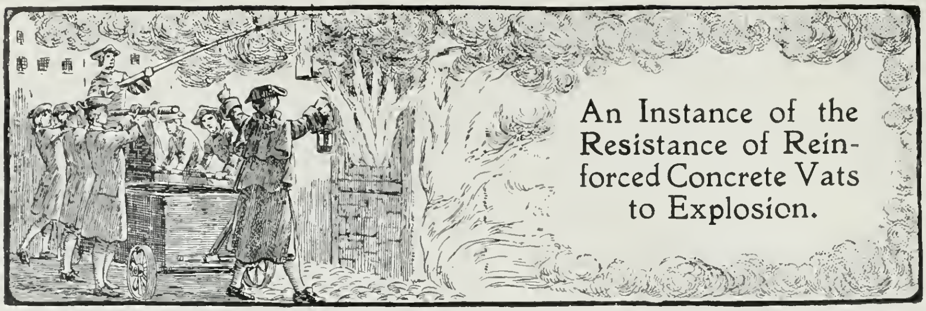
Gradient Posts No. 11 (Reinforced).—These are flat posts 7 ft. long, containing one centre bolt hole through the same. Two small holes for dowels are also provided. These dowels are screwed on to the gradient board in such a position as to give the required angle.

Oversailing Blocks Nos. 3 and 4.—Are made so as to fit exactly the oversailing courses in lieu of the brickwork at the top of platform walls, ready to receive the platform coping. Generally they are used to raise the height of existing platforms. Their height, 1 ft. 1 in., is usually found to be exactly what is required to bring existing old platforms up to standard height.

As ordinarily only short lengths of platform can be dealt with at one time, these oversailing blocks are found both easy to fix and handle when space and time are naturally limited.

Station Name Board Posts No. 10 (Reinforced).—Are special posts to hold station name-boards exhibited at each end of station platform. They have slots at the side into which the name-boards fit, and are adapted for either boards with a single or double row of letters. As an additional stay an iron bolt is run along the top of the boards, through the posts, thus holding all together.

The aggregate which is used in making the articles shown in the last illustration is slag which is crushed and very fine. It is, however, always kept exposed for a considerable period and well weathered, so that all sulphurous matter has disappeared. In the gauging 4 or 5 parts of this is added to one part of Portland cement—Arlesey Co.'s Eddystone brand—according to what is being made, and the result fully demonstrates that the blend is most satisfactory.



An Instance of the Resistance of Reinforced Concrete Vats to Explosion.

The following article and illustrations have been sent us by Mons. N. de Tedesco, Paris.—ED.

THE object of this article is to draw attention to two curious observations made in Argentine; the great resistance of reinforced concrete vats to a serious explosion, and the complete waterproofing obtained by using a layer of mortar applied according to a method devised by M. Millot, constructional engineer.

Messrs. Genoud, Benvenuto, Martelli and Co., proprietors of a distillery at Baradero, Argentine Republic, insured for the sum of £108,000, had three reinforced concrete vats constructed for them by M. Millot, each one being of 44,000 gallons capacity, with light covers, merely intended to check evaporation. These vats were erected under the shelter of a shed, enclosed on all sides by walls of masonry, 1 ft. 6 in. thick, and covered by a reinforced concrete terrace. This shed, 106 ft. long, 46 ft. wide, and 17 ft. high, was only separated from the distillery by a lane 20 ft. wide.

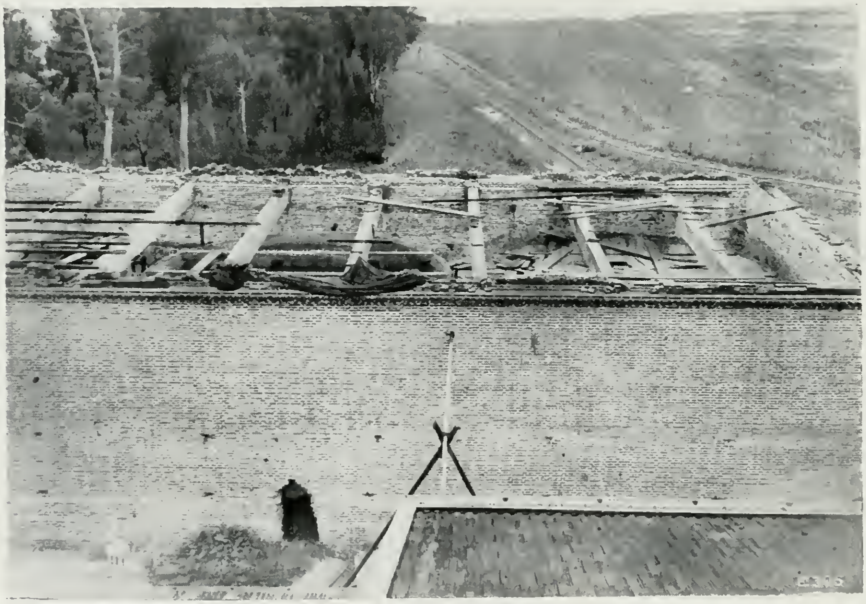


FIG. 1. SHED BEFORE COMPLETION.

In May, 1910, two years after the completion of the vats, the shed was struck by lightning, and an explosion of sufficient violence to shatter the walls to ground level occurred. The reinforced concrete terrace carried by these walls naturally collapsed on to the vats, and the photographs show fragments lodged in the light covers, which were crushed in the fall. The vats contained

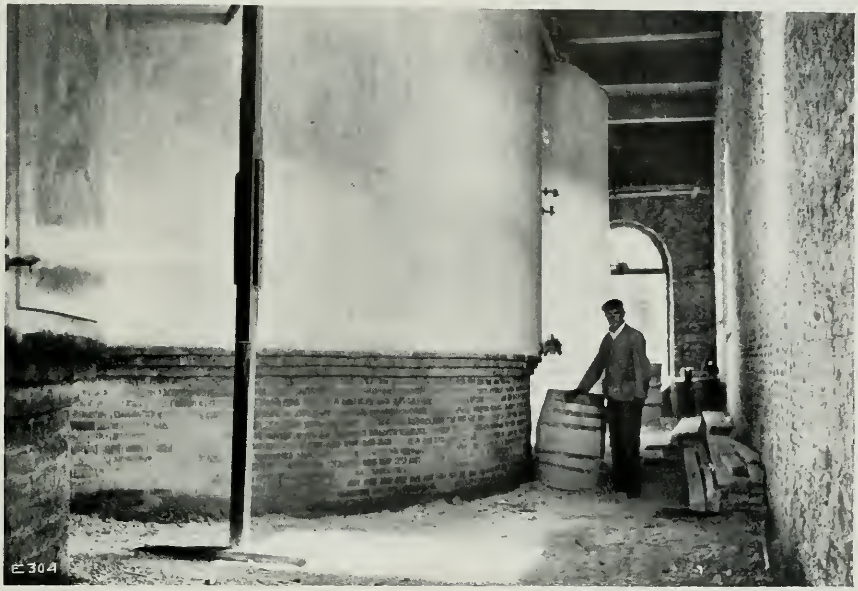


Fig. 2. Arrangement of the Vats in the Shed.

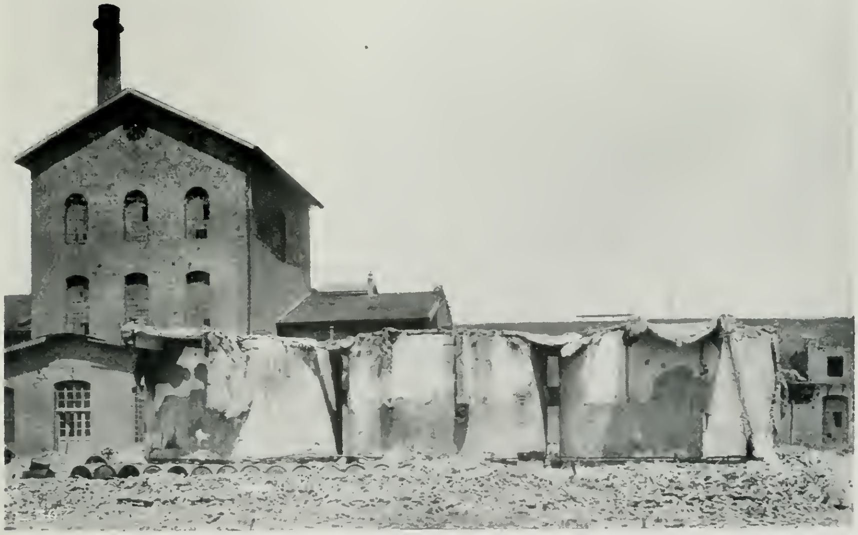


Fig. 3. The Vats after the Explosion.

altogether 95,000 gallons at the time, and the alcohol catching fire, the fire soon extinguished itself, the vats being closed by the débris of the terrace.

The explosion, which reduced the walls to dust, left the vats uninjured, except for their covers and the external layer. The insurance companies escaped with the payment of £2,080 for the walls and the slight damages to the vats mentioned above. Had the vats been constructed of iron plates, as the insurance companies wished, the 95,000 gallons of alcohol would have been burnt, and the flames might have destroyed the whole factory.

It is well known how difficult it is to render concrete watertight, especially towards such liquids as alcohol, by means of a simple surface layer. M. Millot, the engineer, has applied a process to the internal surface of these vats, which he has found perfectly successful in all cases. This process consists in preparing a polished surface layer by the following treatment, which must be rigorously observed.

The surface is prepared by applying successive thin coats of 1 : 1 mortar, without any pause in the application, which involves the employment of three shifts of workmen, each of four plasterers (not including labourers) relieving one another night and day.

M. Millot has in this way constructed 32 vats of 44,000 and 54 vats of 22,000 gallons, without the slightest dampness having appeared on the walls. He required the reservoirs to be filled within the three days following the application of the last stroke of the trowel in forming the final coat. At this time the concrete surrounding the reinforcement would be six to eight days old, according to the capacity of the vats, as given above, and M. Millot holds, rightly or wrongly, that the concrete should undergo its final hardening when fully loaded. In any case, the vats he has constructed have justified his procedure eighty-six times over.

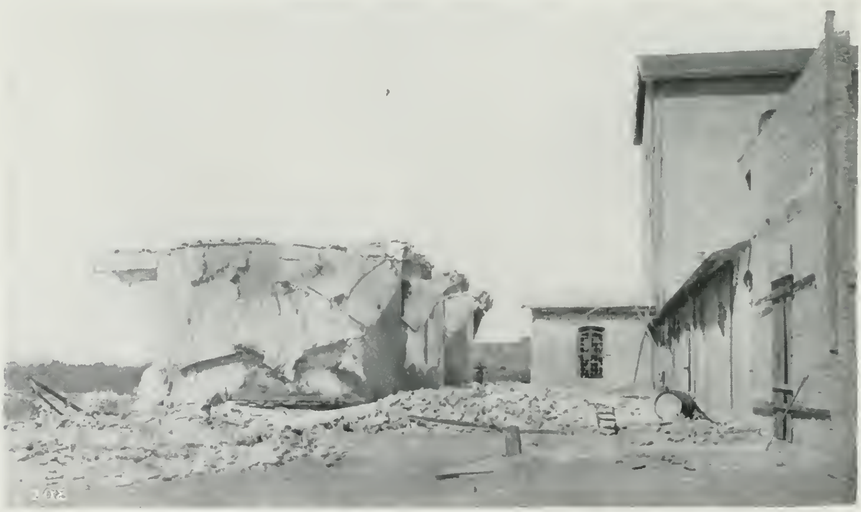
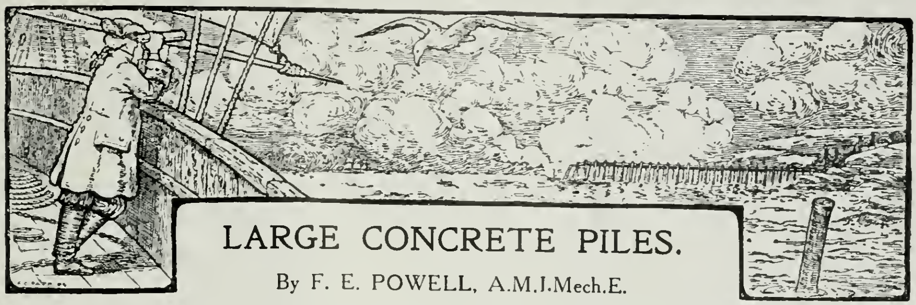


Fig. 4. The Vats after the Explosion.



LARGE CONCRETE PILES.

By F. E. POWELL, A.M.I.Mech.E.

The following article on Concrete Piles will no doubt be of interest to engineers and others engaged in harbour work, etc.—ED.

In the course of his address to the Concrete Institute (reported in this Journal last December) Professor Henry Adams remarked upon large concrete piles and quoted some examples. The largest piles he mentioned were those at San Francisco, 91 ft. long, 20 in. sq., and weighing 15 tons. Perhaps a few notes on the making and driving of much larger reinforced concrete piles will be of interest, and will serve to show what substantial work is being carried out in a quiet way in other parts of the world.

The Port of Auckland, New Zealand, has been completely modernised during the last ten years on the lines of a scheme prepared by Mr. W. H. Hamer, M.Inst.C.E., Engineer to the Auckland Harbour Board, and all the more important wharves are in reinforced concrete. The construction of the largest of these—1,200 ft. long by 281 ft. wide—required nearly 2,000 piles, and borings showed that in some places it was over 100 ft. from deck level to rock bottom, with some 50 ft. of mud and clay overlying it. The rock is a soft sandstone of excellent bearing power, and even the clay would carry considerable weights, but it was felt that unless the piles were driven to refusal there must be doubt as to the girders and beams, all of which were designed as continuous over the supports.

It is well known that in designing long reinforced concrete piles the chief difficulty is to provide against stresses during handling. Previously the largest piles employed in the harbour works had been about 70 ft. long by 18 in. sq., and these were hollow. These were handled and driven without serious difficulty, although in the opinion of the writer, who was then chief assistant engineer, they were often severely strained. As it was his concern to design the larger piles now required, much thought was given to the method of slinging, and he was fortunate enough to hit upon the scheme shown in the accompanying diagram (*Fig.* 1), which simplified the question of design considerably. The pile is carried by a wire rope made fast at its ends, but running free through the three-sheave block and the two snatch-blocks secured to the pile. The latter has to be up-ended and controlled by other ropes until in a vertical position alongside the pile-driver frame.

Although the scheme was simple in this form, a large amount of work was necessary before it could be put into execution. Fortunately the Board had an

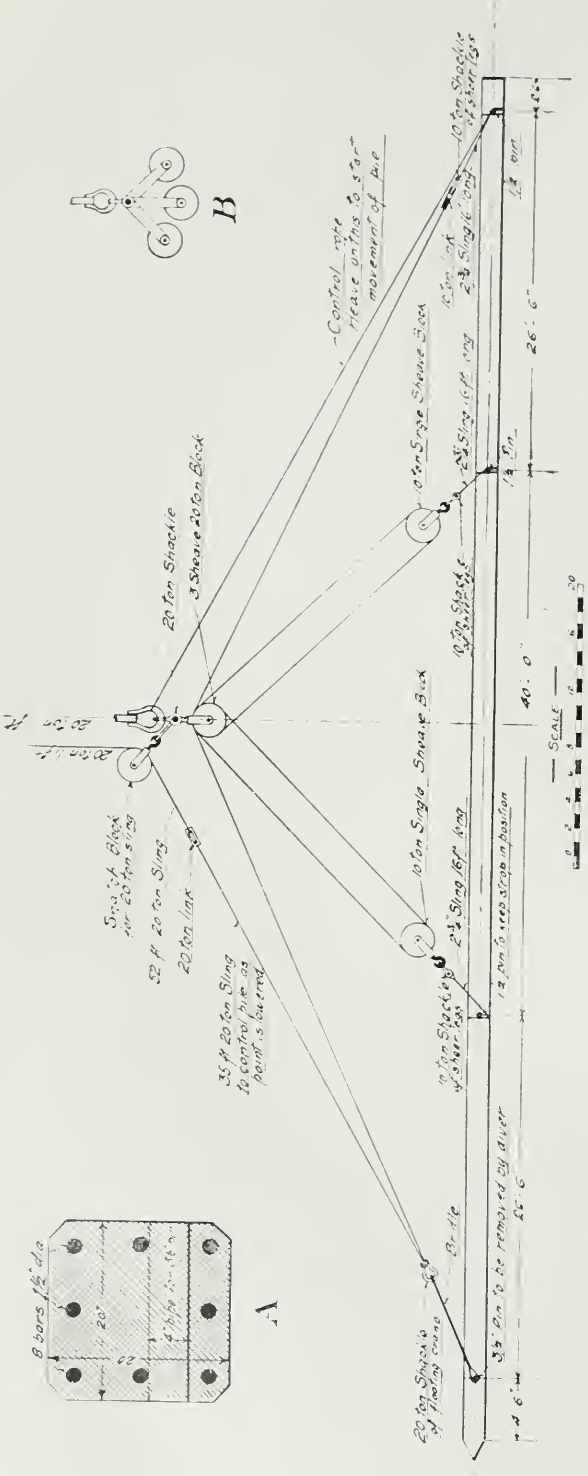

A
8 bars 1⅝" dia
20"
20"
4" pipe for jet
B
20 ton Shackle of floating crane
Bridle
3½" Pin to be removed by diver
25' 6"
4' 6"
1½" pin to keep strop in position
10 ton Shackle of shear legs
2¼" Sling 16ft long
10 ton Single Sheave Block
35 ft 20 ton Sling to control pile as point is lowered
20 ton link
52 ft 20 ton Sling
Snatch Block for 20 ton sling
20 ton lift
20 ton lift
20 ton Shackle
3 Sheave 20 ton Block
40' 0"
SCALE
10 ton Shackle of shear legs
10 ton Single Sheave Block
2¼" Sling 16ft long
14' 0"
26' 6"
10 ton link
2¼" Sling 16ft long
10 ton Shackle of shear legs
Control rope to start heave on this to start movement of pile

Fig. 1. Method of Slinging Long Concrete Piles.
LARGE CONCRETE PILES.

80-ton floating steam crane which could be used to assist operations. Then the calculation of the proper points of support had to be made to suit the safe moments of resistance of the pile, having regard to the fact that the rope has equal stress throughout its length (being free to run in all the pulleys), while its angles of inclination to the pile vary with the slope of the pile. Bending moment diagrams were therefore made for each point of support over the range of movement, and various positions tried until the worst bending moments were always within safe limits. The writer suggests that these varying conditions might make a good practical study for a class of engineering students. The section of pile shown at " A " in the diagram was adopted as a trial and found to meet the case. This section was used for all the piles from 60 to 100 ft. long, the shorter ones being slung from two points only. It may here be remarked that wherever practicable without great loss of economy it is better to have as few changes of section as possible in reinforced concrete work, as it is less likely to lead to errors in construction.

The first practical difficulty was to find suitable slings, ropes, strops, etc. Again, most fortunately, the gear belonging to the floating crane and 80-ton sheer legs provided all that was required, including a 20-ton three-sheave pulley for main lift. Diagrams were prepared to show in what way the gear was to be used, where to be joined, and so on. The operations were rehearsed in dummy, especially to make sure that those in charge understood each step. Another practical difficulty had been foreseen in that with the tallest pile machine the point of the pile would be close to mud level when the pile was straightened up, and as there was a 3½ in. pin at lower end to be removed by diver just prior to driving it was decided to make no piles longer than 100 ft., although it might mean building-up in some cases.

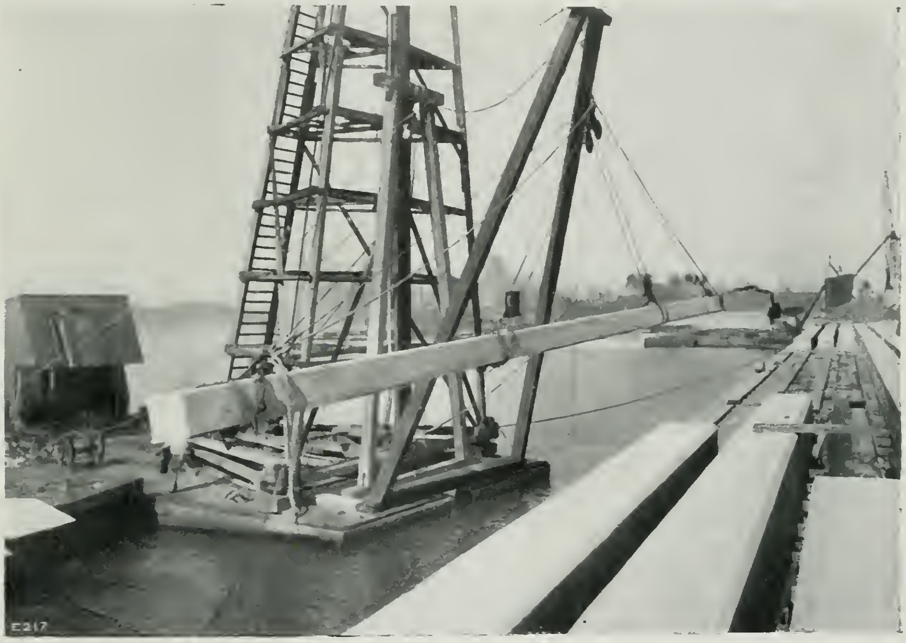


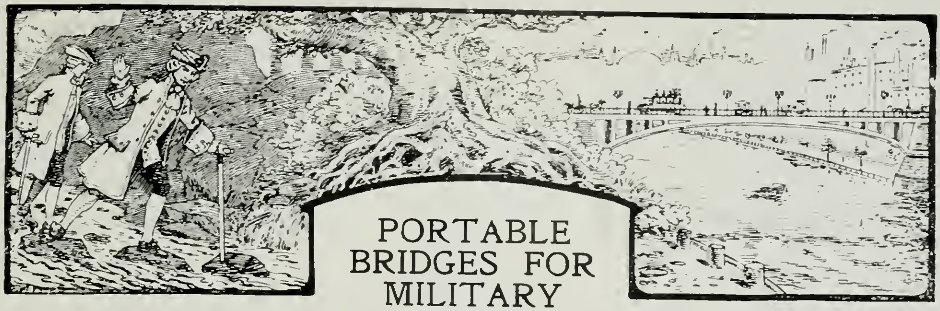
Fig. 2. Lifting a 100 ft. Concrete Pile.
LARGE CONCRETE PILES.

Although involving considerable expense, it was thought wise to make a test with one experimental pile, and this one was made hollow. Later all the piles were made solid, the extra weight and small extra cost being considered less serious than the danger of displacement of core, etc. The lifting of this experimental pile proved the practicability of the method, but demonstrated several minor troubles. The three-sheave block jammed badly under the load, and a block of the type shown separately at " B " in the diagram, having the sheaves all in the same plane, was then made. It also became apparent that the pile-driving plant would not stand up to the work, but this had been anticipated and a new pile machine was being built, having a derrick 94 ft. high, with five ton monkey worked by a Lidgerwood friction drum pile-driving winch.

Deflection of the pile at any position during lifting was very small. The central portion remained practically straight and the maximum deflection at either end was about $1\frac{1}{4}$ in. This was expected from the calculations. The photograph, *Fig.* 2, which shows one of the later piles, clearly indicates this point.

A large number of these piles, varying from 60 to 100 ft. in length and from 12 to 20 tons in weight, were subsequently made and driven. Only one was broken, by being lowered on to a projection on a punt. The piles were mostly driven home to the estimated depths, but only by long-continued hammering. It was necessary in this class of material to continue driving to refusal. An interval of even an hour will allow the clay to set around the pile, and it is then difficult to restart it. A few of the piles did not appear to penetrate to the depths indicated by borings, and having regard to this fact, and the great expense of the piles themselves and the operations in connection with them, it would probably be better to adopt a system in which absolute reliance had not to be placed on the immovability of the pile.

The foregoing was an interesting class of work which required a combination of designing and works experience. Much was foreseen by those assisting in the design and calculations, and the advice of men used to lifting operations was sought, but did not avert many troubles. This is only to be expected, as such men naturally did not see the force of some of the theoretical arguments. Thus it was in the drawing office that a difficulty was foreseen in regard to carriage of the piles on punts, even the largest and strongest of these having too much deflection to suit the resisting moments of the piles, and special punts had therefore to be built. It was found, in fact, necessary to appoint one of the design staff to superintend actual operations throughout, and to deal with any special occasions that might arise. The good results obtained certainly justified this course, and, speaking generally, reinforced concrete constructions, in the writer's opinion, should be superintended by men having more theoretical knowledge than is usually the case. Indeed, it is one of the few cases where the theoretical man can be well employed on outside work, since it is better in this instance to err on the side of minute attention to detail.



PORTABLE BRIDGES FOR MILITARY ROADS AND EMERGENCY BRIDGES.

The following particulars, taken from an article in "Beton u. Eisen" by Dr. Emperger, on Portable Bridges for War Emergency Work, may be of interest to Royal Engineers and others engaged on military engineering constructions.—ED.

Emergency bridges have hitherto been constructed almost exclusively of wood, on account of the ease of handling. Where wood is scarce, especially in the form of large beams, a substitute is required, such as is described in the present article.

For emergency bridges in the field only floating bridges (pontoons) and bridges constructed of ready-made girders, which may be pushed over the supports, come into consideration. Pontoons are only practicable where there is a sufficient depth of water and are useless over marshes. The other type is difficult to erect where the banks are high and steep, although a railway bridge of this kind was erected by the German engineer corps in Northern France with piers 16 metres high and 6 metres wide, with a span between successive piers of 6 metres. This perhaps marks the limit of what is attainable with wood. On account of these difficulties such streams and marshes form the best defences.

Military authorities have proposed to construct temporary bridges up to 45 metres span, but this seems quite impracticable, and it appears probable that 21 metres represents the greatest length of girder that it is practicable to push into place in the direction of its length. A steel bridge of the type shown in *Fig.* 1 can only be used in lengths of less than 25 metres, and even then the setting in place without scaffolding is extremely difficult. Moreover, the distribution of stresses in a structure of this kind is so uncertain that a very high factor of safety has to be allowed.

A satisfactory type of temporary bridge is required not only for military purposes, but in civil engineering practice. When a temporary bridge is required during the erection of a permanent structure it is usual to construct it in wood on the spot, in which case it cannot be used again after being dismantled. There is also frequently a need for temporary bridges in mountainous districts after the destruction or damage of the ordinary bridges by sudden floods.

The types at present employed for military purposes include light girders, triangular framings, and the "Kohn" rhombic frames shown in *Fig.* 1, the cumbrousness of which is obvious. This form has been employed in the replacement of many of the bridges of Galicia and East Prussia, although it is now known that trials by the Austrian Army in peace time had revealed many defects. The Eiffel system, which is also largely used, was subjected in 1887 to a loading test, which resulted in the collapse of the bridge. It has to be remembered that such structures must have a high factor of safety to provide against shocks, such as those due to the passage of motor batteries, etc. It is desirable that stresses should be transmitted by broad bearing surfaces rather than by slender bolts.

In all these systems the preparation of the sections occupies so much time that the construction of new sections as required is impracticable; they must be available ready made. The author now puts forward a system which allows of construction on the spot, the wooden moulds being all that need be ready beforehand. As an example a bowstring bridge is taken (*Fig.* 2). This is built up of "arch units" in two different lengths of 2·1 and 2·8 metres respectively. These units are made up of cast-iron upper and lower members, enclosed in concrete, and externally reinforced (*Figs.* 3 and 4). These parts are light and easily handled, the only massive portions being the ends, shown in black in *Fig.* 5. The joint between two units is shown in *Fig.* 3. A hinge is formed, and wooden blocks are used to tighten the joint, as in the fixing of rails on sleepers. The method of suspending the roadway is seen in *Fig.* 5.

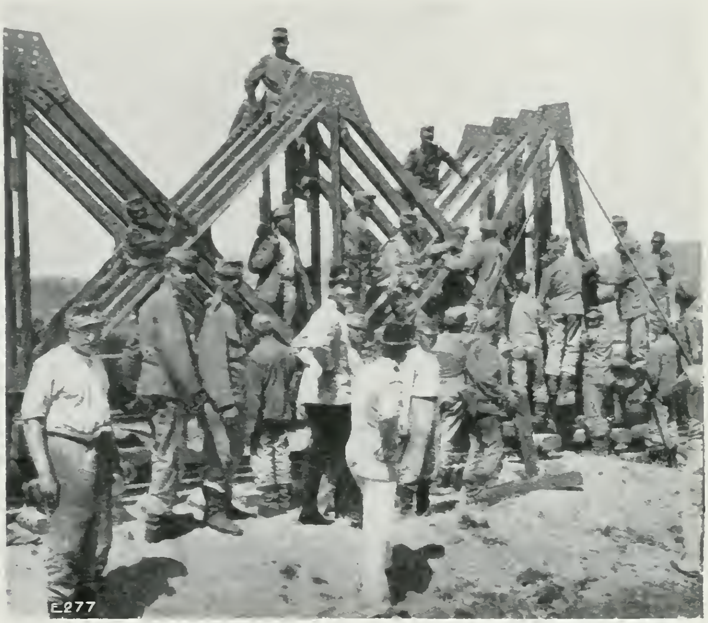


Fig. 1. Austrian Engineers erecting a Military Railway Bridge with rhombic units.
PORTABLE BRIDGES FOR MILITARY ROADS AND EMERGENCY BRIDGES.

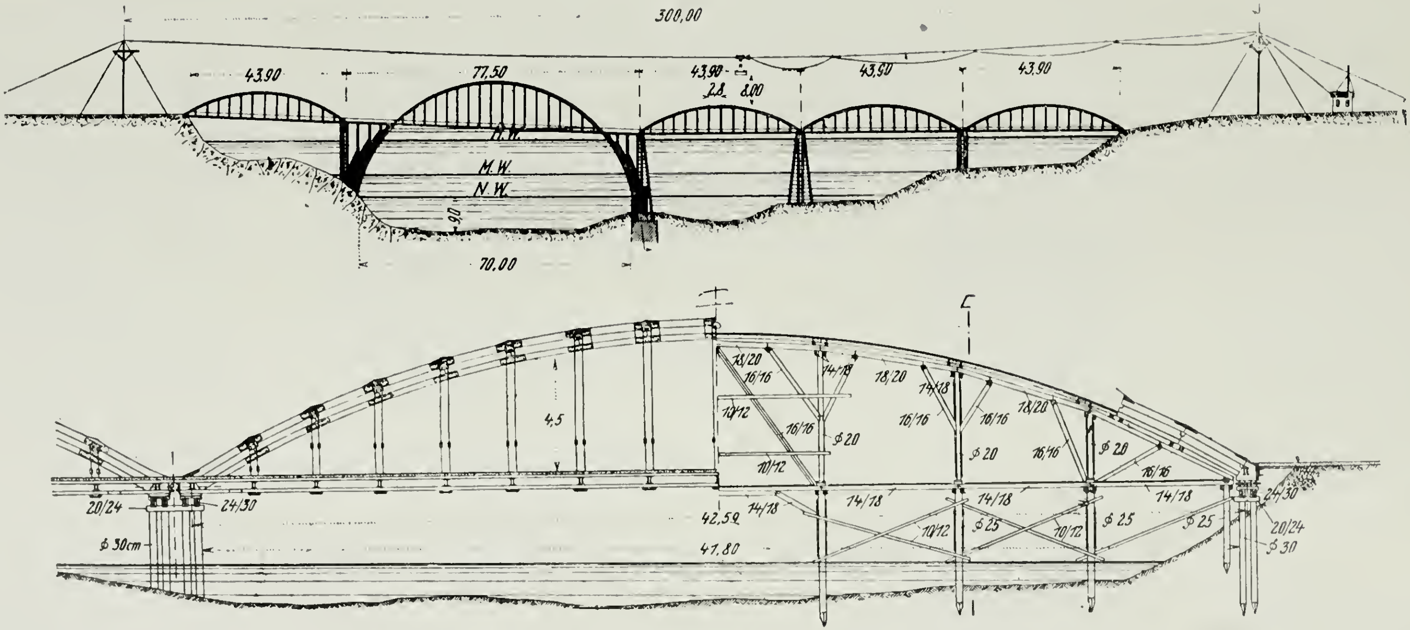
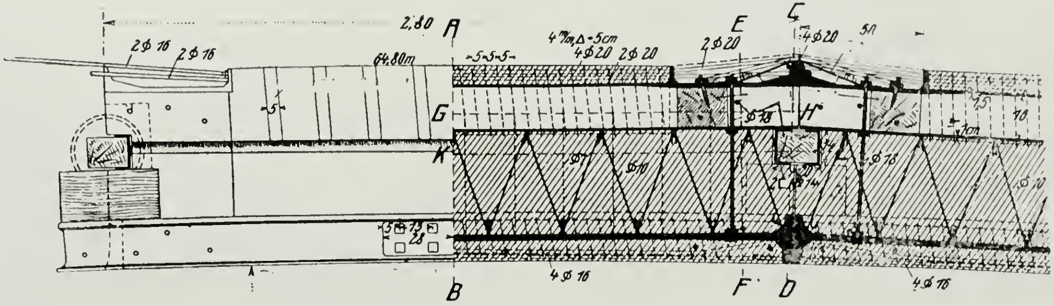


Fig. 2. View and Section. Centering during Erection.

Fig. 3.
Inner Side.



Mid Section

Portable Bridges for Military Roads and Emergency Bridges.

In constructing the bridge the required distance is first divided up into suitable spans and the requisite trestles erected. Next the arches are constructed on the bank, using only the bulb-iron. The heavy ends and the bent T-joists are then put in place, and the coincidence of all bolt-holes tested for, etc. The form being thus determined the centering is erected and the light arch placed upon it, as shown in the right-hand half of *Fig.* 1. This stiffens the light centering, and also determines all the points of the arch. It is erected on wedges so as to allow of quick removal. Next the arch units are pushed along between the T-joists. These units, which weigh 1,400 kg., are best lifted and conveyed by a cable transporter, but a winch and three-legs may be used, or even, in case of necessity, the units may be pushed on rollers to their place. The cable transporter simplifies the work greatly, and as such are to be obtained, and even hired, almost anywhere, it should be used for all but the smallest spans, and erected at the same time as the trestles. The units are laid from the abutments inwards, any small irregularities being adjusted by lead sheeting or cement grouting. They are then bolted together from the centre outwards, the transverse connections being made at the same time. The arch is now self-supporting, and is completed by filling cement mortar between the metal parts through the channels provided, and the wedges may be removed. No welded joints are made, but only bolts are used, together with joints tightened with wooden wedges and protected by cement.

Next the suspending rods are attached, and after removing the centering the cross-beams are attached, the lengths of the suspending rods adjusted, and the roadway, 22 cm. thick, constructed in any suitable manner.

The construction is the same for spans requiring from 12 to 18 arch units, that is from 35 to 48 metres, the radius of curvature of the arch being 40 m. For larger spans a flatter arch of 52 or 64 metres is used, wedges being inserted between the units. Such alterations as are necessary to the steel parts can be made on the spot, only the tension member requiring special strengthening, which is easily carried out.

The arch units are curved to a radius of 64 m., so that with an arch of that span they make a continuous circular arc; with smaller spans the arch is somewhat polygonal, the deviations from circular form amounting to 5 or 10 mm. The T-section guides are correspondingly shaped. When a different radius is adopted these guides must be bent in a rail-bending machine and the bolt-holes adjusted.

The computations have been made for a span of 43 metres, assuming three arch units and two T-guides throughout, so that with greater spans or higher loads four or more units may be used, whilst two suffice for smaller spans. Using spans of 42·6 m. each 1,500 metric tons of iron are required for each kilometre of such a bridge. It is essential that the cost of such bridges should be so low that stretches of several kilometres may be constructed by military engineers over marshes or flooded land. The construction of such a road, capable of carrying troops and munitions, is impracticable with the ordinary types of military bridge on account of the high cost and the numerous piers required.

It is considered that a single span of this type may be erected and used in eight days after the material arrives at the spot. A method of constructing piers for rapid streams, likewise of reinforced cast-iron, is also described.

An example of bridge construction in the present war is given. The German engineers had to replace a bridge over the Meuse immediately next to a destroyed tunnel. Temporarily avoiding the tunnel the piers of the old bridge were utilised to protect the new trestles from the action of the rapid current, being further protected by sinking sacks filled with concrete. In this way ordinary wooden trestles could be used. A steam crane was procured from a neighbouring factory, and the 90 piles required were cut from an old wood. Electrical current to drive the saws and drills was obtainable in the town. The piles were driven 2 metres into the bed of the river by four

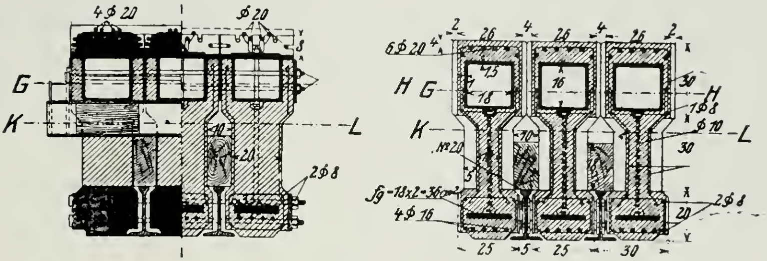


Fig. 4. Sections.

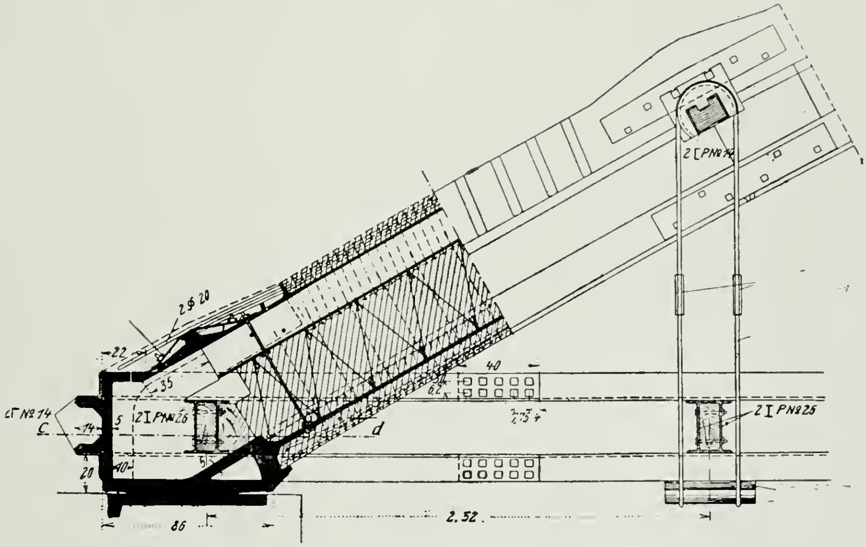


Fig. 5. Suspension.

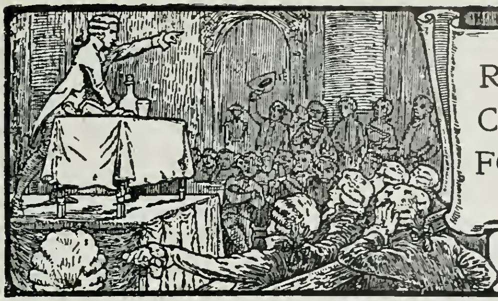
Portable Bridges for Military Roads and Emergency Bridges.

hand-driven pile rammers. Each of the four trestles required 18 piles. Special broad-flanged I-beams were rolled in Luxemburg of the unusual length of 17 metres. These beams, 30 in number, weighing 2½ tons each, were conveyed from the Luxemburg rolling mills on a motor-wagon 11 metres long. On these beams the sleepers and rails were laid. In this way, with 400 men, working day and night, the span of 16 metres was bridged between September 18th and October 2nd. The time required would have been very much greater had not the abundant resources of Belgium been available, providing machinery of all kinds, and had not the Luxemburg mills been near at hand. Had the system here described been used, only a single pier need have been constructed, or even a pier of the old bridge utilised, whilst only half the time would have been required, even in a non-industrial district.

Bridges constructed in the manner here described are easily dismantled, even long after erection, and the component parts may be used again elsewhere.

MEMORANDUM.

Municipal Loans.—The precise periods during which loans granted to municipalities for various classes of electrical machinery should be repaid have been a source of continual discussion and controversy ever since the electric-lighting industry was first established. With greater experience of the characteristics of each particular piece of plant, some degree of standardisation was arrived at which was satisfactory for a certain length of time. The first loans granted in London, for instance, were for an average duration of 42 years, irrespective of the actual variations in the lives of the various portions of the plant. That principle, however, has long been recognised as distinctly unpractical, and the Local Government Board later on instituted varying periods. This has been the policy for many years; but it has taken much persevering effort on the part of central station engineers to bring home to the Government officials that progress is constantly being made in the reliability of plant, and that these periods need revision from time to time. It is true that the periods have been increased; but even now there are certain anomalies which the Institution of Electrical Engineers has within the past few months been endeavouring to bring home to the appreciation of the Local Government Board. It is not so very long ago that only 15 years were allowed for cables, notwithstanding that resurrected pieces from the ground have, after 20 years, still had the whitewash clinging. At the moment, however, 25 years is allowed, and no increase will be allowed upon this. Storage batteries, hitherto allowed five years, however, are to have 7 years, but there has been a refusal to increase the period for reinforced-concrete work. At present 15 years is allowed, and 30 years was asked. The period for the repayment of loans for reinforced-concrete work is causing considerable heartburning among structural engineers generally. Experience and tests indicate that first-class reinforced-concrete work has an almost everlasting life, and to insist upon loans for such work to be repaid in 15 years strikes the ordinary individual as a little curious.—*Electrical Engineer.*



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

RECENT PAPERS & DISCUSSIONS.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE INSTITUTION OF CIVIL ENGINEERS.

The following are abstracts of two Papers read at the Ordinary Meeting of the Institution, on Tuesday, November 30th, 1915.

(1) HARBOUR AND COAST-DEFENCE WORKS AT ALEXANDRIA, EGYPT.

By DAVID ERNEST LLOYD-DAVIES, M.Inst.C.E.

THE city of Alexandria possesses two harbours, known locally as the western and eastern ports. The former, which is under the jurisdiction of the Ports and Lights Administration of the Egyptian Government, is by far the most important commercial harbour in Egypt; the latter, which is being developed by the municipality, is at present only available for light-draught and pleasure craft.

After brief allusion to the history of the city, the Paper describes the development of the Western Port under Mohammed Ali Pacha, Said Pacha, and Ismail Pacha. The important scheme of development decided upon by the last, which was designed by Mr. Linant de Bellefonds, the Minister of Public Works, included the construction of the breakwater from Ras-el-Tin point, the construction of the principal coaling-jetty, and the construction of quays, having a total length of 2,950 yds., between the main coaling mole and the old careening basin, embracing the reclamation of 305,000 sq. yds. of frontage. The total cost of the scheme amounted to £3,011,400, though the value of the reclaimed land was estimated at £833,000.

The first improvement of the access to the port was undertaken in 1889 and consisted in the deepening and widening of the Boghaz Pass, the only fixed channel. High and low lighthouses were built to give the leading line at night, the higher light being visible for a distance of ten miles.

In 1900, the Gabbary dry dock was built by the Khedivial Mail Steamship Company after the designs of Sir Benjamin Baker.

In 1893, the western extension of the quay, south of the old careening basin, was undertaken.

The general expansion of commerce in the port and the consequent lack of quay-space rendered imperative the removal of the timber trade, which had increased in value from £288,000 in 1884 to £1,337,000 in 1907, to a more convenient site. For the quays and storage sheds an area of about 420,000 sq. yds. of land was reclaimed and levelled, and three moles, each 131 yds. long and 87 yds. wide, 60 yds. apart, were constructed. The depth alongside is 30 ft. and the quay frontage 1,225 yds., which will allow nine ships to be berthed at one time in case of necessity. The main breakwater and the quarantine jetty were also extended to protect the timber quays.

The breakwater extension was built on a sea-bed of silt by the Croizette-Desnoyers system of penetration.

The contract for the two moles was executed by Messrs. Edward Almagia and Sons in twenty-seven months. The total expenditure was £217,900, and the work was completed in 1908, but the damage done to the seaward face of the moles has shown that :—

(1) The face blocks should have been carried to 33 ft. instead of 16 ft. below low water. This has been remedied by laying additional blocks at a cost of £20,000, to protect the slope, which had been flattened by sea action to 3 to 1.

(2) The upper part of the structure on the harbour side was not stable enough to withstand the impact of the falling water. This defect is being got over by encasing the exposed rubble in masonry.

It has been found that portions of the breakwater which lie opposite the openings between a series of submerged reefs some distance out on the sea side are more attacked than others.

The quays south of the old careening basin were lengthened and widened at this time, and a reinforced concrete stores was built.

Mr. Maiaval, previously Chief Engineer of the Ports and Lights Administration, applied his adaptation of the Croizette-Desnoyers system with much success. The method consisted of tipping selected filling over a breadth considerably more than the base of the finished section. The tipped mound was carried up to a sufficient height to force the filling into the unstable ground, the filling being continued until it was stable at ground level, and subsequently a considerable surcharge was added over and above the finished level of the work. After absolute stability had been obtained with the surcharge, the surplus material was removed and the work was completed to the designed levels. The author has applied this system with encouraging results for carrying a main outfall sewer embankment over ground which would not carry the weight of an average man.

A small jetty, with a depth of 23 ft. alongside, has lately been constructed in reinforced concrete on the caisson principle. A beacon on the Grand Pass was recently constructed on the same principle and floated into place.

The western port of Alexandria now ranks third, after Marseilles and Genoa, among the Mediterranean ports, and its 1,850 acres of sheltered area are capable of accommodating 250 large vessels 100 yds. apart. The total tonnage of the ships entering and leaving the harbour increased from 2,052,000 tons in 1880 to 7,814,000 in 1908, whilst the value of import and export trade rose from £18,856,000 to £52,075,000 during the same period. The revenue in 1911 reached £325,000.

The Eastern Port. — The deplorable condition of the foreshore in the eastern harbour, owing to the direct discharge of sewage into the bay, induced the Alexandria municipality in the early 'nineties to consider proposals for the amelioration of the existing state of affairs.

It was finally decided :—

(1) To construct a promenade with a sea-wall, of suitable design to resist the roughest sea, around the eastern harbour, and to lay a main intercepting sewer along its entire length, with outfalls at both Kaid Bey and Silsileh.

(2) To abandon any idea of building breakwaters to protect the harbour.

(3) To construct a promenade with a sea-wall and intercepting sewer around Anfouchy Bay.

The promenade has an overall width of 95 ft., divided into two carriage-ways, a central platform, under which are laid the main intercepting sewer, gas, and water mains and electric cables, and inner and outer footpaths.

Mr. Quellennec, who was consulted as to the sea-wall sections, advised the adoption of three types.

The first, for the most exposed positions, consisted of an embankment of loose graded stone resting in the mixture of mud and sand on a dredged foundation, and was faced with 17-ton concrete blocks offsetted to a slope of 45°. The masonry walls rest on the mass.

The second and more economical section, built with a vertical face, was made use of where the depth did not exceed 10 ft. It was judged necessary, however, during the progress of the work to strengthen the toe by the addition of a rubble apron graded to a slope of 1 to 1 and composed of stones ranging in weight from 1 to 2 tons. The apron extended from water level.

The third section was chosen for the western side of the bay, which is protected by the Kaid Bey promontory, and where the depth of water varies only 2 to 5 ft. It is composed of a simple rubble mound, 8 ft. wide at the top, with an outer slope of

1 vertical in 3 horizontal, and an inner slope of 1 in 1, supporting a dwarf masonry wall.

The whole undertaking was carried out in the years 1900-4 at a cost of £377,000, inclusive of the intercepting sewers and the filling of the 630,000 sq. yds. of reclaimed land. The total cost was approximately £500,000. By the sale of reclaimed land the enterprise would have yielded a profit of at least £500,000 had all gone well, but unfortunately the violence of the sea had been underrated, and the waves during stormy weather washed over the sea-wall, inundating the promenade and adjacent property.

The author, who was appointed City Engineer of Alexandria in the autumn of 1906, was instructed to report on the matter. Investigation revealed the fact that a portion of the toe of the section had been scoured out in the most exposed places, and that the 17-ton blocks had slipped forward. The impact of the waves hurled huge masses of water to a height of 26 ft., and the force of the blow was calculated to be at least 1·56 ton per sq. ft. The whole of the additional apron of 1- to 2-ton stones in front of the vertical section was washed away, and the masonry was attacked, whilst the air compressed by wave-action drove jets of water through the mound (the lightest of the three sections) to a height of 3 ft. in the roadway. Evidently, therefore, the initial error was the omission of the breakwater.

Three alternative remedies were proposed:—

(1) The construction of breakwaters at the mouth of the bay, at a cost of £220,000.

(2) The construction of smaller breakwaters within the bay, at a cost of £180,000.

(3) The addition of a long rubble bank gently sloping towards the toe of the wall to reduce the velocity of the breaking waves, at an estimated expense of £130,000.

The first alternative was chosen, as it served the triple purpose of protecting the sea-wall, creating a fine pleasure harbour 600 acres in extent for the city, and providing an additional refuge for light commercial craft, which appeared quite to justify the additional expenditure. The length of the Kaid Bey branch is to be 547 yds. and average depth of water 26 ft.; the Silsileh arm will be 765 yds. long in 16 ft. of water. The width of the entrance will be 383 yds. and the depth 30 ft. The foundation consists of hard sand.

The section is an adaptation of Pascul's Marseilles composite type, with the outstanding feature of a double slope, 1 in 1 up to water level, and afterwards 1 in 3 for the pell-mell blocks on the exposed face.

The pell-mell and set blocks, weighing 40 tons, are composed of 5 parts of broken limestone, 2 parts of sand, and 1 part of hydraulic lime. The variation allowed for the voids in the pell-mell mass is between 25 per cent. to 35 per cent., to give an average of 30 per cent.; special precautions with regard to the first course of blocks were taken to lay them accurately endways at the toe, in order that they should offer as small a face as possible to the impact of the sea.

It was decided to undertake the Kaid Bey branch first, and Messrs. Schneider and Company have the work in hand.

The storm conditions at Alexandria vary from year to year to a remarkable extent, so that, by fortuitously encountering a bad year, the contractor might be unjustly penalised; to avoid this it is agreed that any day during which the wind blows for any complete hour with a velocity exceeding 15 miles per hour, no matter what the direction may be, is to be regarded as a *dies non*.

Under the author's main-drainage scheme for the city, on which £350,000 will be ultimately expended, all sewage is to be conveyed to a pumping station at Kaid Bey, and discharged half a mile out to sea at Y, the depth of water at that point being 82 ft., and the set of the tidal current being westward. The present outfalls will, under the new conditions, be utilised as storm-water outlets only.

Stability of Breakwaters. — The methods employed for the estimation of the strength of breakwaters seem in many instances to be shrouded in mystery. Professor Luigi Luiggi has lately discussed the stability of the breakwaters of thirteen different harbours of the world, and has traced a pressure-curve for waves of translation which is adaptable to a dynamic or breaking wave of 20 ft. to 25 ft. in height, with the maximum pressure at ordinary sea level of 2·79 tons per sq. ft. This height of wave and consequent pressure is not the greatest met with, but the curve can be modelled to meet the conditions of the locality.

The critical positions lie between the depths of 12 ft. and 33 ft., *i.e.*, where the rubble mounds of composite breakwaters generally end and the superstructures begin; and many disasters have been caused by the employment of insufficiently heavy material for the rubble at this point, or the adoption of too steep a slope.

The Luiggi curve can be also utilised for calculating the resistance of a breakwater against overturning and against displacement, or sluing.

In conclusion, attention is drawn to the notable advantages of the employment of huge reinforced concrete caissons filled with concrete so as to produce one monolithic mass in the construction of breakwaters.

(2) GALVAN PORT, BAHIA BLANCA, ARGENTINE.

By CHARLES ALFRED TERRY, M.Inst.C.E.

THE town of Bahia Blanca lies at the head of a deeply indented bay of the same name, along the north-east side of which a channel, navigable by ocean-going craft, extends to a point some five or six miles above Galvan Port, or nearly 50 miles from the open sea. Except for this channel the whole estuary is encumbered with islands and banks.

From about 14 to about 30 miles below Galvan Port the channel is about two miles wide, forming an excellent deep-water harbour, with good anchorage. This reach is named "Puerto Belgrano," and at its upper end the Argentine Government has established a naval port with dry docks. In the neighbourhood of Bahia Blanca, which is five miles away from the shore of the inner harbour, the channel has a width of about 1,500 ft. between banks at low water, the depth ranging from 18 to 26 ft., with excellent anchorage. The mud banks are fairly steep below low water, but flatten out above that level to a slope of about 1 in 100. The tides, which are affected by winds blowing up and down the estuary, have a normal range of about 14 ft., but as much as 22 ft. has been recorded, the level of high water in this case being about 5 ft. 4 in. above normal.

Only two small streams or brooks now enter the estuary, and these carry little water except at times of thunderstorms. The considerable tidal currents maintain the depth of the "inner harbour." The banks, being of a fairly solid clay mud, are not easily eroded.

Bahia Blanca has enjoyed port facilities since 1883, when the Buenos Aires Great Southern Railway Company commenced the construction of jetties which form part of their present port at Ingeniero White.

In 1889 the Bahia Blanca and North Western Railway Company came into existence and constructed a pioneer railway from Bahia Blanca towards the north-west into the Pampa Central Territory. The oversea traffic of this line was dealt with at the Buenos Aires Great Southern pier until 1901, when, to cope with the increasing traffic, the Bahia Blanca and North Western Company commenced the construction of a jetty of their own, the "Puerto Galvan" of to-day, which forms the subject of the Paper.

After a careful study of the locality by the author, a site for the proposed works was chosen at a point where the Galvan creek joined the main channel.

The soft nature of the mud, together with frequent rough water at high tide, rendered the survey of the site extremely difficult. Trial piles were driven and borings made from temporary timber stages. It was found that the "tosca" (a calcareous formation very general in these regions) was covered at the site of the port by a layer of indurated sand of varying thickness. The level of the "tosca" at the edge of the channel being about 27 ft. below low water, an excellent foundation was assured at a convenient depth.

Generally, the "tosca" in this part of the country is of rock-like hardness, but at the port it was found to be sufficiently soft to be worked with pick and bar, or to be excavated by bucket-dredger, provided the buckets were suitable.

The mud, the mean level of which is, at the site of the works, 6 to 7 ft. above low water, is a homogeneous deposit free from gravel or sand, very soft on the surface where covered at high water, but increasing in firmness with the depth; it is of sufficient consistence to stand at a steep angle under water when newly cut into. The layer of mud has an average thickness of about 27 ft., and is practically watertight.

Preliminary Works.—As a preliminary to more permanent and extensive works to be undertaken as the traffic of the port developed, it was decided to construct a timber jetty of sufficient size to accommodate two large ocean steamships as well as some smaller craft.

The many difficulties encountered in the construction of the jetty were chiefly due to the physical features of the site. The timber employed was pitch-pine, the piles being 50 ft. long. As the teredo abounds in the water of the estuary the timber was treated with "carbonileum avenarious," with results which quite surpassed expectations.

Permanent Port Works.—In 1904 the Buenos Aires and Pacific Railway Company took over the Bahia Blanca and North Western Railway and Port on a working agreement; and the preparation of a definite scheme for the port works was undertaken by the author, who had then been appointed Chief Engineer of the Buenos Aires and Pacific Railway.

In designing the works, the following points were kept in view:—

1. The works should be of a thoroughly permanent nature, the use of steel or timber under water being avoided.
2. The design should admit of the work being carried out intermittently as required; any portion completed to be available without impeding, or being interfered with by, the construction of subsequent portions.
3. As large an area of land as possible should be reclaimed; all material dredged being used for levelling up the reclaimed areas.

The general scheme approved by the Argentine National Government embraced a frontage on the main channel of 1,000 metres from the Galvan Creek down-stream. The principle generally adopted was to provide each ship's berth with independent accommodation and independent sidings.

The works consist of a series of jetties, slightly inclined down-stream, to facilitate the entrance of vessels. These jetties have a length of about 2,000 feet, jutting out somewhat beyond the low-water line of the main channel, and they increase in width by steps from their outer extremity inwards, each step marking the limit of a ship's berth; this arrangement not only lends itself to the provision of independent sidings, but leaves valuable land available for marshalling-yards, warehouses, etc. At the same time the basin is wider towards the mouth, thus giving free movement to ships, no tugs being needed by steamers either entering or leaving the port.

The type of the quay-wall and the method of construction were matters for serious consideration, in view of the difficult nature of the site.

The author decided to adopt a form of concrete wells or cylinders. The type of cylinder selected was that with three wells. The cylinders were monolithic and were reinforced with vertical and horizontal steel bars. With this method of construction the staging required is comparatively small and can be repeatedly re-used; while the fact that the bulk of the sinking can be done while the water is still in reduces the pumping. Three sizes of cylinder were used, for depths of 30 feet, 25 feet and 18 feet respectively, the sections being modified in accordance with the depth. In practice a depth of about 21 feet of water was obtained with the small-sized cylinder, the level of the hard bottom admitting of dredging to that depth.

The angle of the cutting edge was 45 deg. and the cast-iron curb used at first was replaced by old 52-lb. flat-bottomed rails which were found quite effective and much cheaper. A stout plate was riveted to the rail at each angle for the purpose of attaching vertical rods of mild steel, which not only acted as vertical reinforcement, but also supplied a means of suspension during the earlier operations of lowering into the water, or soft mud; they were continuous throughout the entire height of the cylinder, being joined together in 12-foot lengths by long sleeve-nuts. The rails did not give so sharp a cutting edge as the cast-iron curb, but this was no disadvantage in the soft mud, and in either case it was found necessary to undercut by pick in the hard, to bring about sinking of the cylinder.

The softness of the mud, and the fact that it is covered at high water—and in some cases, on the line of quay, at low water also—made it necessary to conduct all operations from an elevated platform above high water, and to suspend the cylinders during the initial stages of building and sinking from timber gantries. For lowering purposes, each gantry was equipped with twelve 10-ton differential pulley-blocks, one to each of the outer vertical rods of the cylinder.

In carrying out the work the gantry was first placed in position and a temporary platform was fixed to the piles underneath, at a height of about 8 ft. below high water. Upon the platform the curb was put together, the vertical rods were attached, and the first two sets of shuttering were placed in position and filled with special concrete. This was carried out during low water, and the rising tide afterwards covered the work, which was allowed to set for 72 hours. The tackles on the gantry above were then attached to the vertical rods, and the mass was lifted to allow of the removal of the temporary platform. The cylinder was then lowered to within a short distance of low-water level, or to the surface of the mud, as the case might be; the lower shutter was lifted, placed on top, and filled with concrete; the building and lowering were then carried on continuously, the cylinder sinking into the mud until the skin-friction rendered it self-supporting, which usually occurred in the case of the large cylinders when a depth of about 25 ft. had been attained.

The further sinking was effected by excavating from the three chambers.

When the " tosca " was reached, under-cutting was found necessary, and in most cases weight had to be added to get the cylinders down.

The cylinder was finally bedded in the " tosca " at 3 ft. 6 in. below the proposed dredging-level, and all the chambers were sealed with 6 ft. of concrete. The front chambers above this seal were filled to the top with a rough concrete plentifully helped out with large stone " plums," the back chambers being filled with excavated material.

To close the opening between two adjacent cylinders a concrete pile is driven in front and a timber pile at the back. The cylinders terminate about 1 ft. 5 in. above high water, and the wall has a height of 7 ft. 6 in. above the top of the cylinders, is 8 ft. 9 in. wide at the base, and has a batter of 1 in 20 on the outside face. The coping is of mild-steel plates secured in place by hooks embedded in the concrete.

The whole front of the quays is protected by vertical fenders of greenheart timber, from the coping down to lowest water-level; the time occupied in sinking and completing a cylinder averages about 25 days, dating from the laying of the curb.

Up to the present some 4,100 lineal ft. of quay-wall has been constructed.

The work was commenced at many points simultaneously, and as the spacing of the cylinders could not be controlled with any great exactitude, special closer cylinders of larger or smaller dimensions were used as the case required at the meeting-points.

Concrete.—Granite was used for the cylinder work. The only sand obtainable was not very satisfactory and granite screenings were substituted as far as possible.

The following general proportions were adopted for the cylinders: 1 part Portland cement, 2½ parts sand, and 4½ parts crushed washed granite; but for the first two shutters above the curb 1 : 1½ : 2½ concrete was used.

The front chambers of the cylinders were filled with 1 : 5 : 8 concrete, the aggregate used being selected " rock tosca " instead of granite. This " tosca " was also used for the concrete of the wall above the cylinders, the proportions being 1 : 3 : 5.

Dredging and Reclaiming.—The excavation of the basin between the jetties and in the Galvan creek is done by a self-propelled bucket dredger, two sets of buckets being provided, one for the soft mud, and the other for hard sand and " tosca."

Equipment.—There are ten main and four minor berths completed, which are equipped with thirty-four electric derricking cranes of the two-leg braced pedestal pattern, set astride of the outer tracks at the edge of the berths on independent rails, the power ranging from 30 cwt. to 5 tons, with a radius, at full load, of 35 to 25 ft. All these cranes are provided with independent motors for hoisting, sluing and derricking. Nine of the cranes are also equipped with patent elevators attached to the legs, for handling grain in bulk.

Storage and Shipment of Grain.—The chief export of Bahia Blanca is grain, and facilities for the storage and rapid handling of it have been given a primary place in the equipment of the port. There are at this port four distinct grain-elevators combined with storage; three of these are on the wharf side, No. 4 is inland. The total storage-capacity is about 73,000 tons, but the greater part of the installations are designed as shipping-appliances to load grain, the storage-capacity being auxiliary for the purpose of avoiding delay to wagons.

The works were designed by the author, and were carried out by administration under his direction until 1912, when he retired from the Company's service.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

REINFORCED CONCRETE WATER TOWER.

THE accompanying illustrations show a reinforced concrete water tower which has recently been erected on the Coignet System at Ham Green, near Bristol, for additional water supply required by the Ham Green Hospital.

The work was carried out departmentally under the supervision and in accordance with the general requirements of Mr. Lessel S. McKenzie, Engineer of the City and County of Bristol.

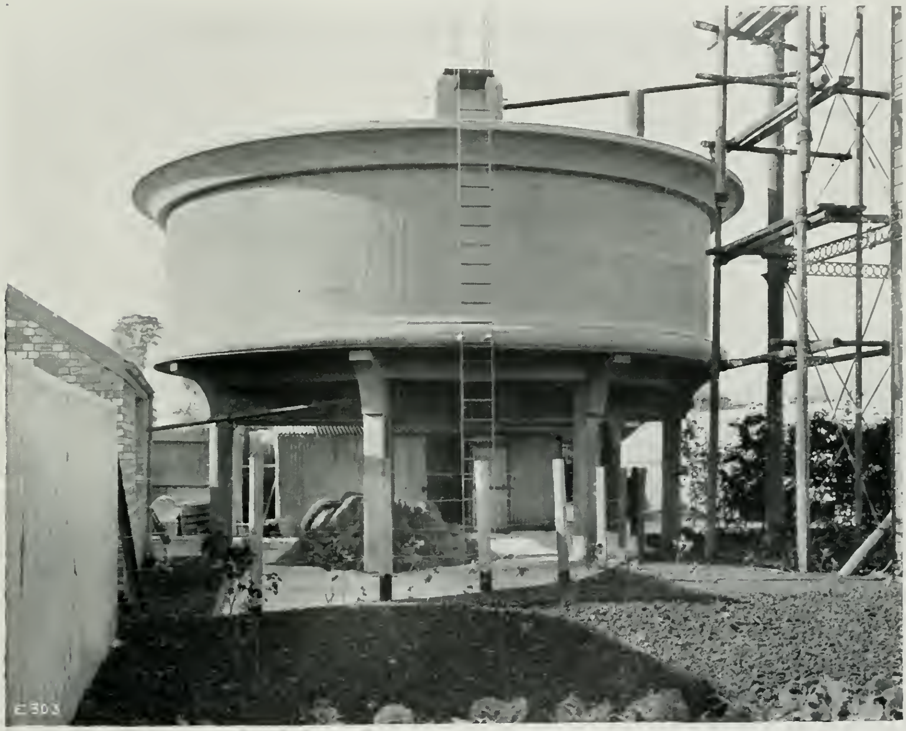


Fig. 1. View of Finished Tower.

REINFORCED CONCRETE WATER TOWER, HAM GREEN, NEAR BRISTOL.

The total capacity of the tank amounts to 40,000 gallons, the general dimensions being 30 ft. internal diameter, with a height of 9 ft. 6 in. of water. The cover is in the shape of a dome, also constructed in reinforced concrete.

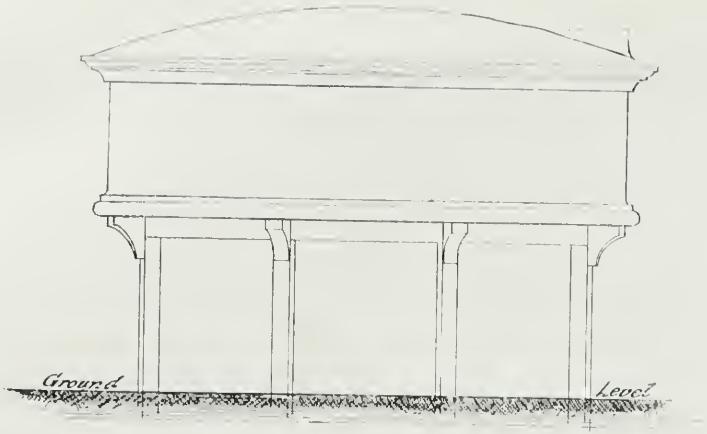


Fig. 1.

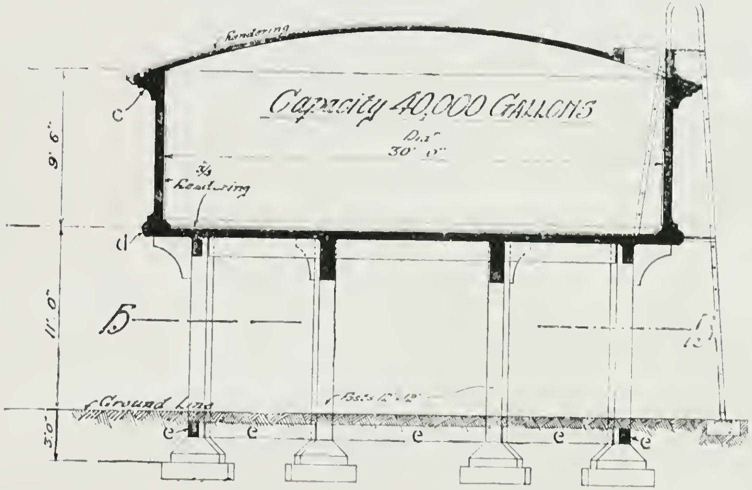


Fig. 2.

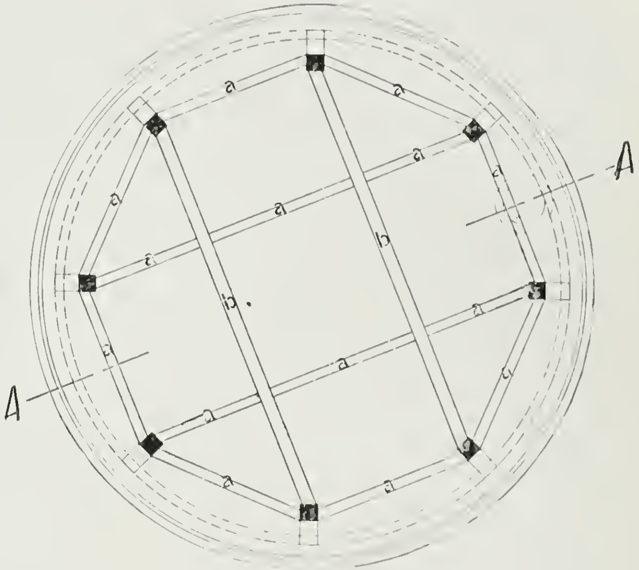


Fig. 3.

Fig. 1. Elevation.
Fig 2. Section AA.
Fig 3. Sectional Plan (locking up).

Reinforced Concrete Water Tower at Ham Green, near Bristol.

This water tower, which is circular, is supported by means of eight 12-in. by 12-in. reinforced concrete pillars 11 ft. above the ground. Reinforced concrete footings and ordinary concrete foundations have been provided to distribute the load in a satisfactory manner on the ground. The bottom of the tank is supported by principal and secondary beams with reinforced concrete slabs 6 in. in thickness, and the circular walls are 5 in. in thickness, reinforced by means of circular bars and vertical rods of small diameter.

The dome, the reinforcement of which is by means of a meshwork of $\frac{1}{4}$-in. bars, is only 4 in. in thickness with a rise of 2 ft. 6 in. in the centre.

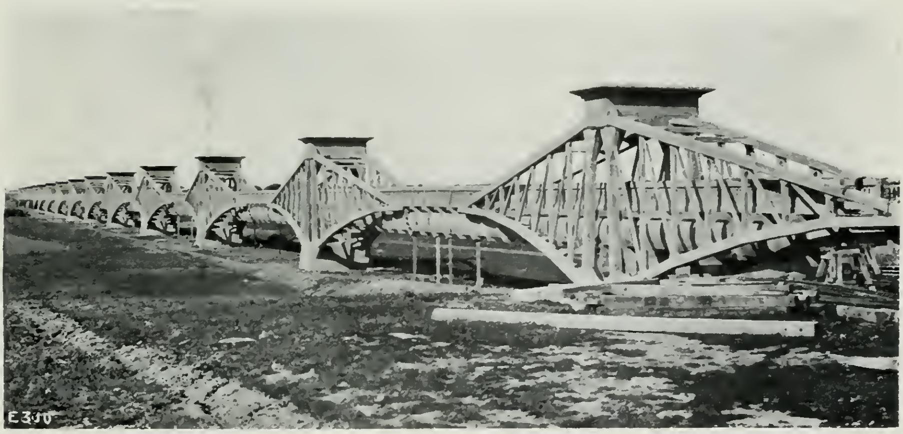
The circular beams taking the thrust of the domed roof and of the water respectively at the top and at the bottom of the circular wall of the tank have been carefully moulded in order to improve the appearance of the work.

The interior of the tank was rendered with cement and Pudlo in order to make the work absolutely water-tight. A suitable manhole with outside and inside ladders has been fixed to give easy access to the inside of the tank for the purpose of inspecting and cleaning the tank.

The Specialist Engineers for the preparation of the working drawings were Messrs. Edmond Coignet, Ltd., of 20, Victoria Street, Westminster.

REINFORCED CONCRETE AQUEDUCT OVER THE RIVER BARWON, AUSTRALIA.

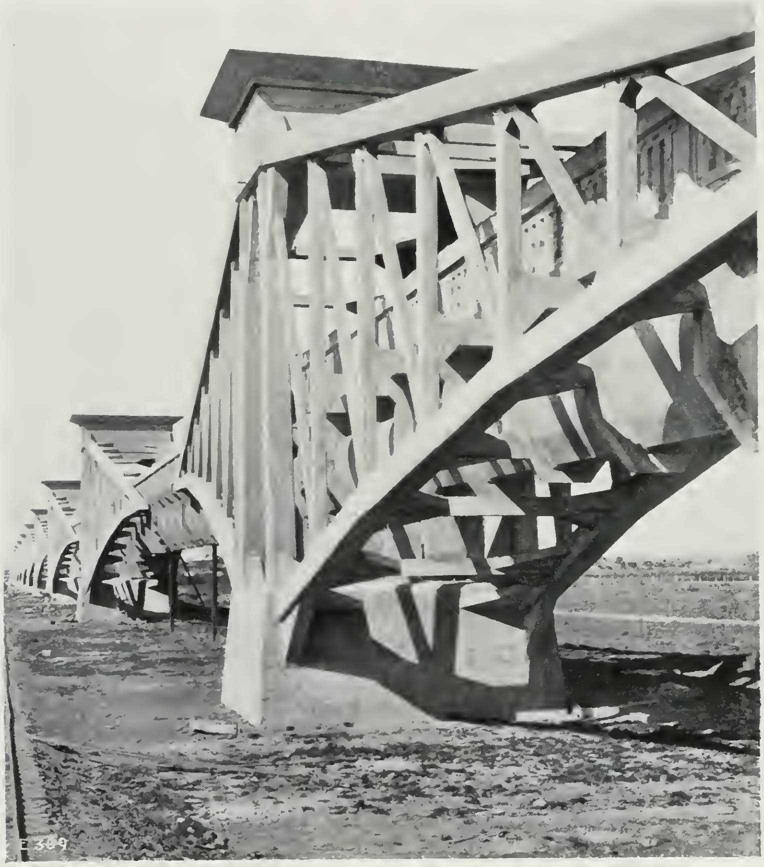
Geelong, one of the leading cities in Victoria, Australia, recently installed a sewerage scheme in which reinforced concrete has been widely used. It was necessary to cross the River Barwon and river flats with the sewer line. On the recommendation of Mr. R. T. McKay, A.M.Inst.C.E., Chief Engineer to the Water Works and Sewerage Trust, Geelong, it was decided to erect an aqueduct. Alternative prices in steel or concrete were submitted, and the Trust, after due consideration, accepted the design and tender of Mr. E. G. Stone, Engineer for Messrs. Stone and Siddeley, Reinforced Concrete Specialists of Sydney, Australia.



Reinforced Concrete Aqueduct over the River Barwon, Australia.

The accepted structure is of reinforced concrete and is designed upon the cantilever principle. To cross the river and flats—a length of 2,424 ft.—fourteen spans were proposed, thirteen being 176 ft. and one of 136 ft. centres. The structure is economical, and the work presents many interesting features. One of the great advantages derived by the use of the cantilever is the fact that any variations due to temperature are horizontal, whereas in the case of a series of arches these movements are vertical and would create a series of undulations throughout its length, an undesirable effect, seeing that the grade of the sewer is only 1 in 2,500.

In order to take up the imposed horizontal wind stresses adequately and economically the cantilevers are splayed, the distance between them increases from the point to the piers. The pipes, all of reinforced concrete, are built into the structure; they do not add to its stability. The pipes are oviform in shape, 8 ft. in length, this length coincides with the distance between the vertical struts in the cantilevers, thus the transverse webs between the cantilevers strengthen and support the joints of the pipes. These pipes were constructed by the successful tenderers in the same moulds as the pipes for the main section of the sewer. Bores taken along the site showed that the rock levels varied from 5 ft. to 40 ft. below the surface. Reinforced concrete piles were driven to test, and the reinforcement in these engage with the rafts upon which the piers rest. The bases of the piers were hollow, the space afterwards being filled with plum concrete; from the bases run out the various members; an adequate notion of their disposition can be obtained from the photographs. The reinforcement throughout is of ordinary commercial steel rods, and the disposition of the bars throughout the structure is of extreme interest, the full tensile strength being taken up by laps; in no place are they mechanically connected. The rods in the upper boom are arranged in concentric rings, the laps of which break joint along its length. The diagonals are in tension, and the ends of the rods through them are accurately bent around the rods in



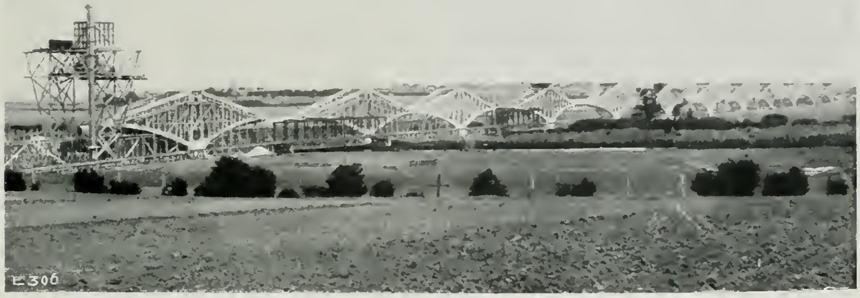
Reinforced Concrete Aqueduct over the River Barwon, Australia.

the upper and lower booms. A footpath is also provided throughout the whole length, and its treatment adds very considerably to the appearance of the work.

The length from point to point of a cantilever span is 136 ft., and across the gap of 40 ft. are placed girders, which in each case are fixed at one end and free to move at the other. The handrailing of the footpath is sufficiently reinforced to act as girder; by this method it was possible to maintain a continuous footpath form.

An expansion joint is provided in each span, its design being similar to that of an ordinary stuffing box.

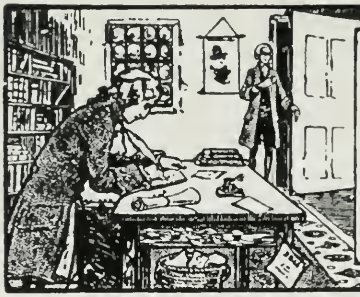
The structure is now almost completed. In the photographs a few of the timber supports are shown; they have still to be removed. It is one of the finest reinforced concrete constructions in Australia.



Reinforced Concrete Aqueduct over the River Barwon, Australia.

MEMORANDUM.

Suggested Railway Causeway.—An ambitious scheme is under consideration for the connecting up of India and Ceylon by a railway. The South Indian Railway has now been extended to Dhanushkodi, and the Ceylon State Railway to Talaimannar, two points distant from each other about 20 miles across a shallow strait. The proposal (according to the Administrative Report) is that a connecting track should be laid on a solid embankment or causeway raised on the sandbank known as Adam's Bridge. This causeway would extend about 20 miles, of which about seven miles would be built upon the dry land of the various islands and 13 miles in water. The section through the sea will be constructed on a double row of reinforced concrete piles driven into the sand, pitched at 10-ft. centres, and having their inner faces 14 ft. apart. These piles would then be braced together longitudinally with light concrete arches and chains, and transversely with concrete ties, struts and chains. Behind the piles slabs of reinforced concrete would be slipped into position, the bottom slabs being sunk well into the sea bottom, and the space enclosed by the slabs filled in with sand. The top of the concrete work would be carried 6 ft. above high water. The estimated cost of the work is £740,000.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Publication of Regulations as to Reinforced Concrete.—In view of the great stress laid upon the necessity for economy at the present time, it is interesting to note the following :—

The Local Government Board having allowed the above Regulations and having decided that they should come into operation on January 1st, 1916, a question arose as to their publication in full in the *London Gazette*. The L.C.C. having been advised that such publication must take place, enquired whether, as no useful purpose would be served, it would not be sufficient to advertise that the Regulations had been allowed, and that copies were obtainable at the Council's offices, the cost of such publication being £180. The Board, while agreeing with the Council as to the utility of publication in full, stated that the language of the Act made such publication obligatory. It was then suggested by the Council to the publishers of the *London Gazette* to utilise the type at present standing, but here H.M. Stationery Office (who are responsible for the publication of the *London Gazette*) intervened, and said they were unable to entertain this proposal. It will therefore be necessary to publish the Regulations in the ordinary way.

The New Dublin Grain Silo.—The members of the Engineering and Scientific Association of Ireland recently paid a visit to the new grain silo which is being erected at Alexandra Road, North Wall, Dublin, by Messrs. J. and W. Stewart, to the design of Messrs. Batchelor and Hicks, architects, to inspect the "C. P." method of reinforced concrete piling which has been adopted on these works.

The members were received by Mr. Hicks, F.R.I.B.A., architect; Mr. T. L. Moore, M.I.M.E., representing Messrs. J. and W. Stewart, the contractors; Mr. J. B. Morrow, local manager; and Mr. J. Woolcock, works superintendent. Mr. Hicks fully explained the drawings of the buildings, and Messrs. Stewart's representatives dealt with the work in progress.

The driver was started on a steel piling tube of about 30 ft. in length, which was driven home; the tube was then filled with concrete and drawn, as explained in the following notes on the system. It was interesting to watch the progress made in the drive Sometimes the 30-cwt. hammer only advanced the pile a fraction of an inch and at other times three or four inches, according to the stiffness of the strata being penetrated.

At the conclusion of the driving the visitors were entertained to afternoon tea, and the President of the Association, Dr. P. C. Cowan, proposed a hearty vote of thanks to the architects and Messrs. Stewart for so kindly inviting the members of the Association to inspect the "C. P." system of piling adopted here. Mr. Hicks replied for the architects, and Mr. Moore, in his reply, regretted that Mr. Stewart, who had intended to receive the guests in person, was delayed in Belfast. All the visitors expressed themselves as very much indebted to their hosts for the demonstration. The following notes on the Silo and "C. P." system of piling may be of interest to those who were not able to be present :—

The building will be 130 ft. by 93 ft. on plan and 136 ft. 6 in. in height from ground level, composed of 32 storage bins and 40 delivery bins, with a total capacity of 14,000 tons. The storage bins will be 88 ft. 6 in. deep to the hoppers by 13 ft.

square on plan, each with a capacity of 360 tons. Above the bins there will be three floors, the first designed for a load of 2 cwt. per ft. super, the second for a load of 1 cwt., whilst the third will be utilised as a roof.

The floor above the bins will project and form a cornice around the building, and this, with the external pilasters, will give a very substantial appearance to the structure. The structure is carried on six rows of 10 columns. The columns are supported on a piled foundation.

As previously mentioned, the piling is being carried out on the contractors' well-known "C. P." (cast-in-place) system, whilst the superstructure will also be constructed on their patented system of reinforced concrete. Stewarts' concrete piles will be used throughout, although it was originally intended to use moulded reinforced concrete piles. The reason of the change was as follows:—To ascertain the correct lengths of the moulded piles which would be required it was arranged to drive test piles, these to be constructed on Stewarts' "C. P." system. After the piles had been driven it was decided by the architects to make a test as to the bearing capacity. Four piles having been selected, each pile being the centre one of a group, a bin was constructed and a load applied of 300 tons, this being equal to 75 tons on each pile. The load was carried without the slightest movement or settlement, the test being so satisfactory that instructions were given to use Stewarts' concrete piles throughout the entire contract.

The Load Applied for the Piles of the New Dublin Grain Silo.

In the construction of the piles a heavy steel tube of 16 in. diameter is driven into the ground with a cast iron detachable shoe. The driving continues until the required set is obtained. The force employed is by means of a 30-cwt. drop hammer actuated by a high speed friction winch. The steel skeleton reinforcement is then inserted in the tube. The skeleton is sufficiently large to leave a minimum amount of freedom whilst the tube is withdrawn over same. This ensures the reinforcement being centrally situated in the piles. The tube is then filled with concrete to a height of several feet above the level at which it is desired to finish the head of the pile. A powerful pulling tackle is coupled on and the tube is slowly drawn out of the ground. As the tube is withdrawn the concrete sinks and expands under the pressure of its own weight, thus filling up tightly and securely the hole formed, the time occupied in the construction of a pile being about one hour and a half. Loads on individual piles vary from 57 to 59 tons. The piles are arranged in groups of four, five, six, and nine piles respectively.

The BRITISH STEEL PILING Co

"ZENITH" PUMPS
SAVE TIME AND MONEY
SEND FOR BOOKLET 64.

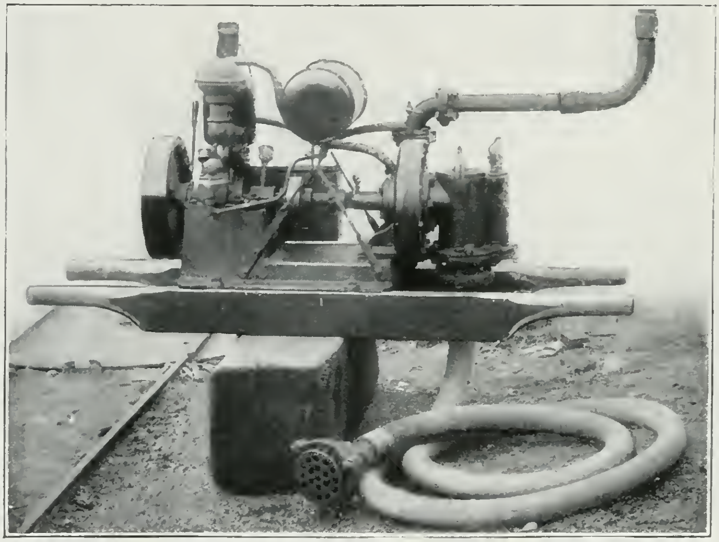


Illustration shows size No 1. It Pumps 3,000 gallons per hour, weighs only 270 lbs., and costs £40 10s 0d. All sizes in stock. "ZENITH" dredge pumps for sand, mud and solids.

DOCK HOUSE, Billiter Street, LONDON, E.C.

Reinforced concrete slabs will be constructed on each group of piles to enable the loads imposed from the columns above to be evenly distributed over the piles.

The columns supporting the superstructure total 60 in number. The loads carried by individual columns vary from 283 to 534 tons.

Concrete Mixers.—According to a report by the United States Consul at Seville there is an opportunity for securing concrete mixers and machinery in Spain at the present time.

CORRESPONDENCE.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—As a contractor I was much interested in reading the address by the President of the Concrete Institute to note his remarks and excerpts from Mr. R. S. Greenman's paper on Reinforced Concrete Failures, particularly the percentages of reasons for failure, which seem to me to be remarkable in the light of our experience in Scotland.

Of four failures in Scotland which have come under my notice, the following have been the reasons:—

1. Concrete Bins.—Bad design, bad workmanship being a contributary cause.
2. Concrete Roof.—Bad design.
3. Concrete Tank.—Bad design, bad workmanship a contributary cause.
4. Concrete Roof.—Carelessness and want of proper supervision, centering drawn too soon.

Mr. Greenman does not seem to have struck any bad design, and this seems to me most remarkable, as my firm find themselves very frequently competing against designs which, on examination, show the margin of safety to be $1\frac{3}{4}$ to 2.

Some of those low margins are due to want of appreciation of the fundamental principles of engineering, some to systematic skinning of quantities, and others to an unfortunate combination of both those faults.

Certain firms seem to go on the principle that when they are in for a particular contract that it must be secured by hook or by crook, generally the latter, and so let their imagination run riot, forgetting entirely the ever-present danger of human fallibility.

Up to a time and point those tactics have been successful in filling their order book, but the damage done by them to the interests of reinforced concrete generally is not easily realised, and it is a pity, to my mind, that some more effective control of design does not exist. I do not suggest how this is to be brought about, but would be glad if something could be done, so that people who offer a decent job would get a decent chance.

I am, yours faithfully,

ALEX. MELVILLE.

PROPOSED WORKS.

Barrow-in-Furness.—Plans for a new power house in Cavendish Park for Messrs. Vickers have been approved.

Newport, Mon.—Foundations for a large warehouse at the South Dock for Messrs Houlder Bros. have been started.

Shoreham.—Messrs. J. Evershed and Son have applied to the Board of Trade for permission to construct a wharf, part of which will be below high water mark, on the north bank of the river Adur.

Canberra.—The Australian Federal Government propose erecting an arsenal at a cost of £95,000.

Lancaster.—The Corporation propose applying to the Local Government Board for sanction to borrow £80,000 for the extension of the waterworks.

Halifax.—The Borough Engineer has been instructed to prepare plans for the reconstruction of Clark Bridge.

Paignton.—Plans by the Borough Surveyor have been approved for repairing the sea wall.

Melbourne.—The Melbourne Metropolitan Board of Works proposes to borrow an additional £1,000,000 for sewage and water works.

Sydney.—The Chief Engineer of the Sydney Metropolitan Board on the extension of the local water supply recommends that the following works should be put in hand: Trunk and sub mains, £1,331,212; local storage reservoirs, £366,715; pumping stations, £450,208; amplification works, £485,540; canal, etc., works, £56,000; new storage reservoir on the Cordeaux River, £446,500.

Colombia.—The Ministry of Commerce are to prepare plans for the carrying out of the following works: Improvement of the port of Purificacion; improvement of the port of Ambaleme; wharf construction at Girardot; and wharf construction at Honda.

Spain.—Tenders are being received at the "Dirección General de Obras Publicas, Ministerio de Fomento," Madrid, for the construction of an embankment on the sea front in the port of Corunna, the estimated cost for which was about £60,000.

Santo Domingo. — H.M. Charge d'Affaires at Santo Domingo states that the construction of a concrete pier, 1,130 ft. in length, and Customs buildings is projected at Puerto Plata.

New Zealand.—The estimates submitted to the New Zealand Parliament by the Minister of Public Works include £700,000 for railway construction, £500,000 for bridge construction, and £427,050 for public buildings.

CHANGE OF ADDRESS.

Messrs. Henry Faija & Co., whose Portland Cement Testing Works are well known to our readers, have removed to 6, Earl Street, Westminster, S.W., where they have secured larger and more commodious laboratories. Any further work entrusted to them in connection with the inspection, testing, and analysis of cement and all kindred constructive materials shall have the same prompt and careful attention as heretofore.

A CORRECTION.

Island Site Hotel. — In further reference to our article on the above in our November issue our attention has been drawn to the fact that a large quantity of material was also supplied by the Expanded Metal Co., Ltd., of York Mansion, York Street, Westminster, S.W., as follows:—6,000 yards super of 1½-in. Diamond Mesh Expanded Steel was used in the concrete for encasing steelwork, over 500 yards super of 3-in. Diamond Mesh Expanded Steel was used in concrete foundations, and a considerable quantity of Expanded Metal Lathing was used in the plasterwork.

THE
VICTORIA
CONCRETE MIXER

1. Centre Ring Construction.
2. External Discharge Chute.
3. Drum ¼-in. Steel Plate.

The VICTORIA is designed for fast and efficient mixing. It will mix concrete faster than you can get rid of it.

The VICTORIA
is built to last

WRITE FOR CATALOGUE No. 29.

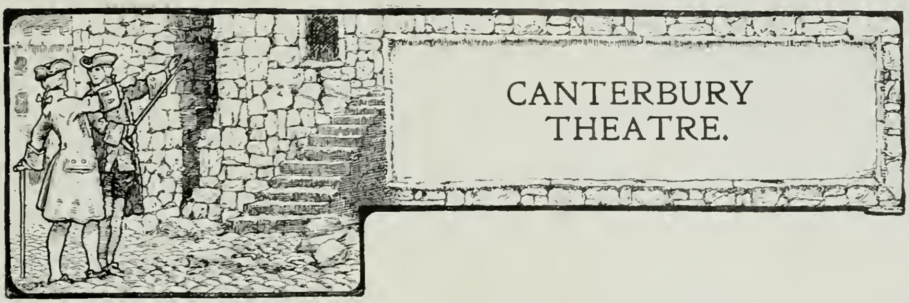
THE
T. L. SMITH Co.
13, Victoria Street, S.W.

The necessity of taking a factor of safety of four for spans over 50 ft., and five for smaller spans was one point put forward. There is no doubt that the factors suggested are quite satisfactory and they should not be reduced.

The questions of getting railway companies to agree to the report, and also obtaining an opinion from the military authorities as to what load they would wish any new bridge to carry, are certainly worthy of consideration, and should, we think, be pursued by the Committee. We cannot see that there is any question of the railway companies being led into a trap, as suggested by one member, because they could very well agree to the conditions of the Report for all new bridges without being under the necessity of rebuilding all the old ones. One might as well argue that the members of the Committee would condemn every bridge in the country that did not comply with the proposed standard loading, and that any municipal or county engineer who worked to the standard in the future would be admitting that all existing bridges in his district which had been erected, to which the standard could not be applied, were inadequately designed. If the Report is to become recognised and generally adopted as the basis of a standard loading, then it must be accepted by those parties who are chiefly interested in the design and construction of bridges. Some remarks were made in reference to the examples being made clearer, by members apparently afraid that the information in the Report might be used by unskilled persons to the detriment of the skilled engineer and possible danger to the public.

We are quite in sympathy with the member who expressed the opinion that anyone who had not an ordinary acquaintance with mechanics should not design bridges, but surely he does not seriously think that anyone who was foolish enough to attempt such a thing would be influenced to any extent by the Report, when there are dozens of books on the market containing a lot of information, and actual examples which he would be tempted to use as a basis. Without a knowledge of mechanics the diagrams and examples in the Report would be valueless to the reader. We do not think there is any need to make the examples clearer, as, in our opinion, they show all that is required; but if it were necessary to make the whole of the matter any clearer there should be no hesitation on account of any fear that the information would be misused.

The Report as it stands should be adopted after agreement, if possible, by the parties previously mentioned, but it seems rather a pity that the whole subject of bridges in reinforced concrete and steel was not taken up and questions of wind pressure, expansion and other matters dealt with by the Committee, and recommendations prepared which would result in standard practice amongst all engineers of repute.



CANTERBURY THEATRE.

Reinforced concrete has been used to a considerable extent in this building, and below we give short particulars regarding the principal points of interest. Our article has been prepared for us by Mr. A. Lakeman, M.S.A.—ED.

THE essential constructional members at this theatre—which has been erected from the designs of Messrs. Jennings and Gray, architects, Canterbury—are executed in reinforced concrete, and the material has proved very successful in its application to this building.

The site is a very irregular one, having a central rectangular portion about 50 ft. wide and 75 ft. deep, with a projecting wing about 30 ft. by 15 ft. on one side at the rear, and a triangular projecting portion about 33 ft. wide and 40 ft. deep on the other side at the front. The plan has been arranged with the auditorium and stage in the central portion and the principal entrance and vestibule in the triangular projection; while the wing at the back is allocated to lava-

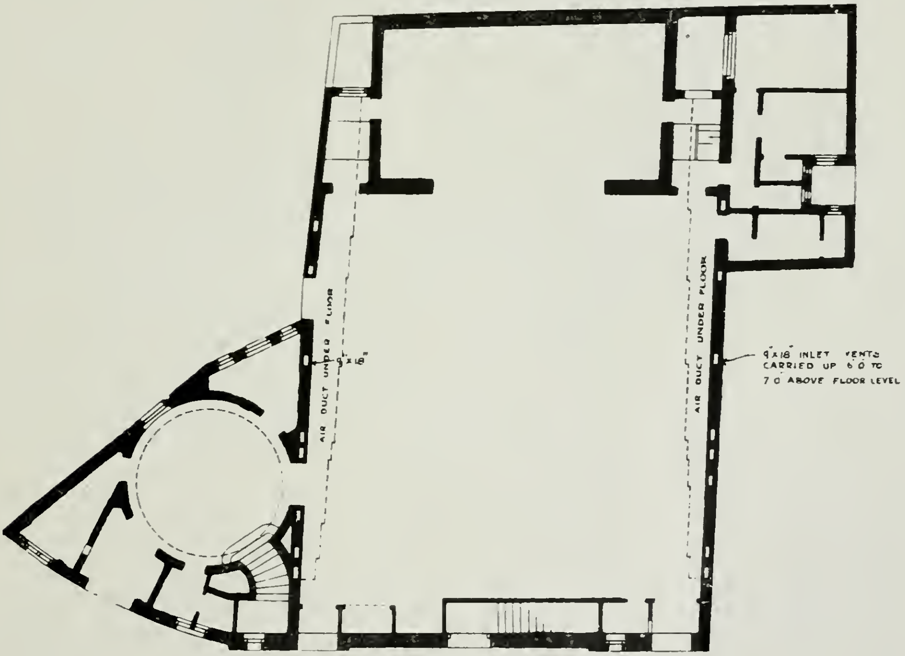

AIR DUCT UNDER FLOOR
9"x18"
AIR DUCT UNDER FLOOR
9"x18" INLET VENTS CARRIED UP 6'0" TO 7'0" ABOVE FLOOR LEVEL

Fig. 1. Plan.
CANTERBURY THEATRE.

tories. There is a small basement under the back of the building, and a balcony is provided over a portion of the auditorium, this being approached by a staircase leading from the main vestibule. An upper floor is also constructed over the back part of the balcony, and here the operating room, etc., are arranged. The stage is 35 ft. wide and about 20 ft. deep, with an opening to the auditorium 19 ft. wide and 17 ft. high. The clear height of the auditorium is about 32 ft., and 30 ft. is provided over the stage. The auditorium has a sloping floor, and space for the orchestra is arranged by a sunk well in front of the stage.

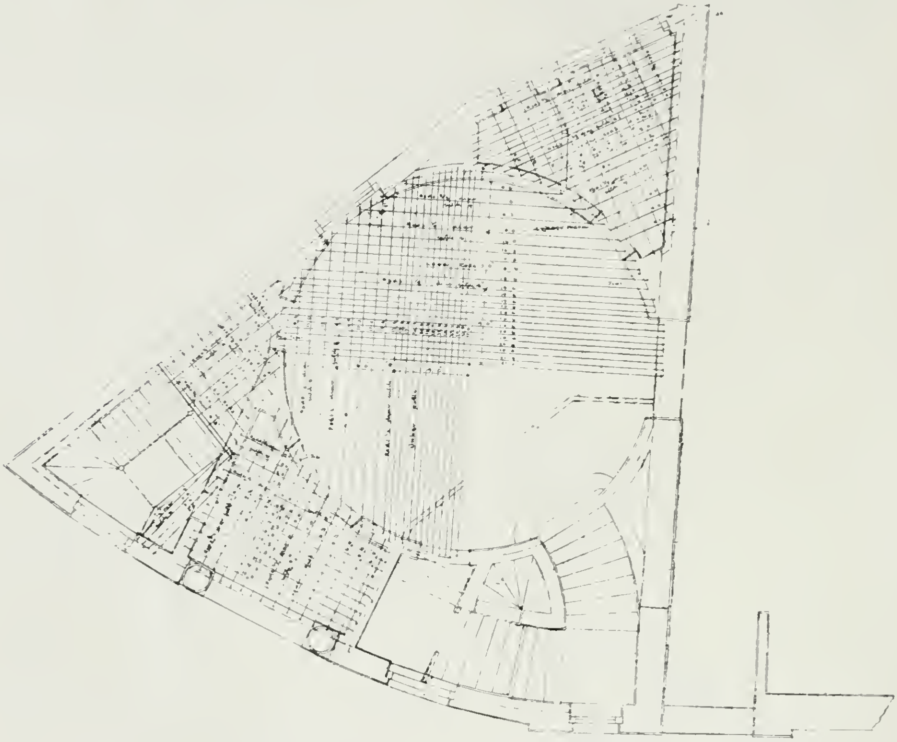


Fig. 2. Floor over Main Entrance.
Canterbury Theatre.

The walls generally are of ordinary brickwork, but reinforced concrete has been used for balcony, beams, staircases, and flat roofs generally, this portion of the work being designed and executed by Messrs. Stuart's Granolithic Co., Ltd.

The plan in *Fig.* 2 shows the reinforced concrete floor over the main entrance, and it will be seen that the main vestibule has been made circular in plan, this working in well with the irregular space available and allowing a successful treatment to be adopted. The floor over this portion is therefore designed and constructed as a circular slab 7 in. thick, supported at the edges, and it is reinforced with ½ in. diameter rods in both directions, these having a pitch of 4 in. for the central portion, increased to 6 in. and 9 in. as the outer circumference is reached. The other portions of the floor generally are constructed with 7 in. of concrete reinforced with ⅜ in. diameter rods at 6½ in. to 9 in. pitch for the main reinforcement and ¼ in. diameter distribution rods at right angles to same. The whole of the floor was screeded and covered with wood blocks, and the concrete was gauged in the proportions of 6 to 1, with ½ in. cover to all rods.

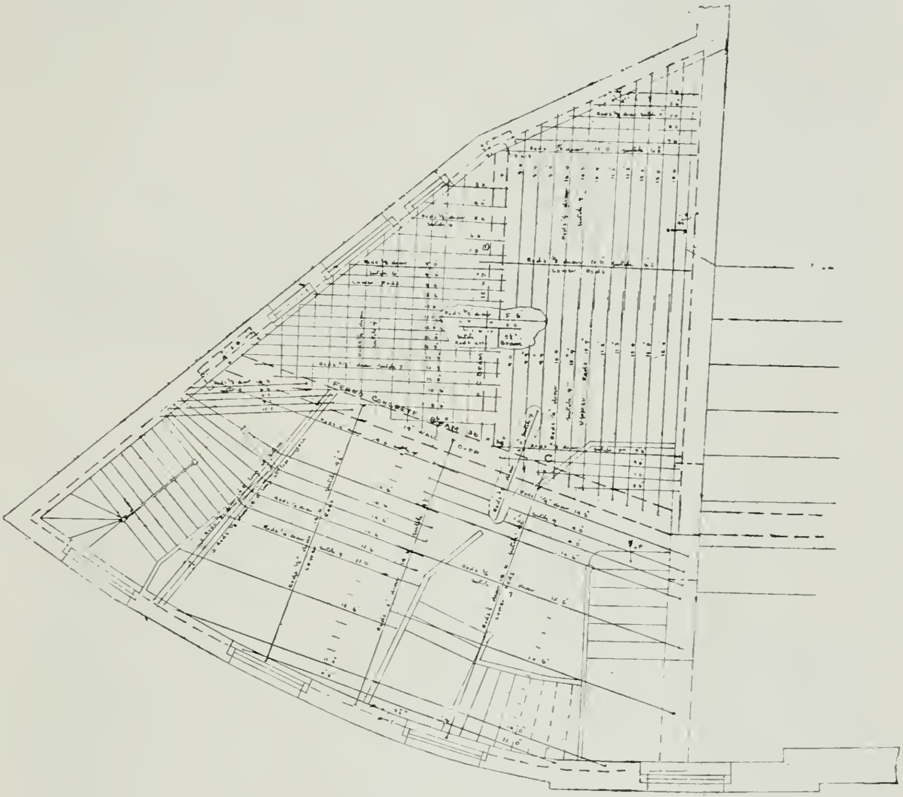


Fig. 3. Floor and Flat at Upper Floor Level.
Canterbury Theatre.

Only a portion of the triangular projection was covered with a second floor, the remainder being finished with a flat roof at this level, and the plan in *Fig.* 3 shows the work at this point. The second floor portion extends back about 16 ft. from the main front wall, and the back wall is carried by a reinforced concrete beam 36 in. by 14 in., having a span of about 24 ft. This beam is shown in *Fig.* 4, and it will be seen that it projects above and below the floor level, and is reinforced with three rods in both upper and lower surfaces, these being 1⅝ in. and 1¾ in. diameter respectively.

In addition to the stirrups seen on the elevation of the beam, the top and bottom sets of rods are tied horizontally by ⅜ in. diameter links bent round

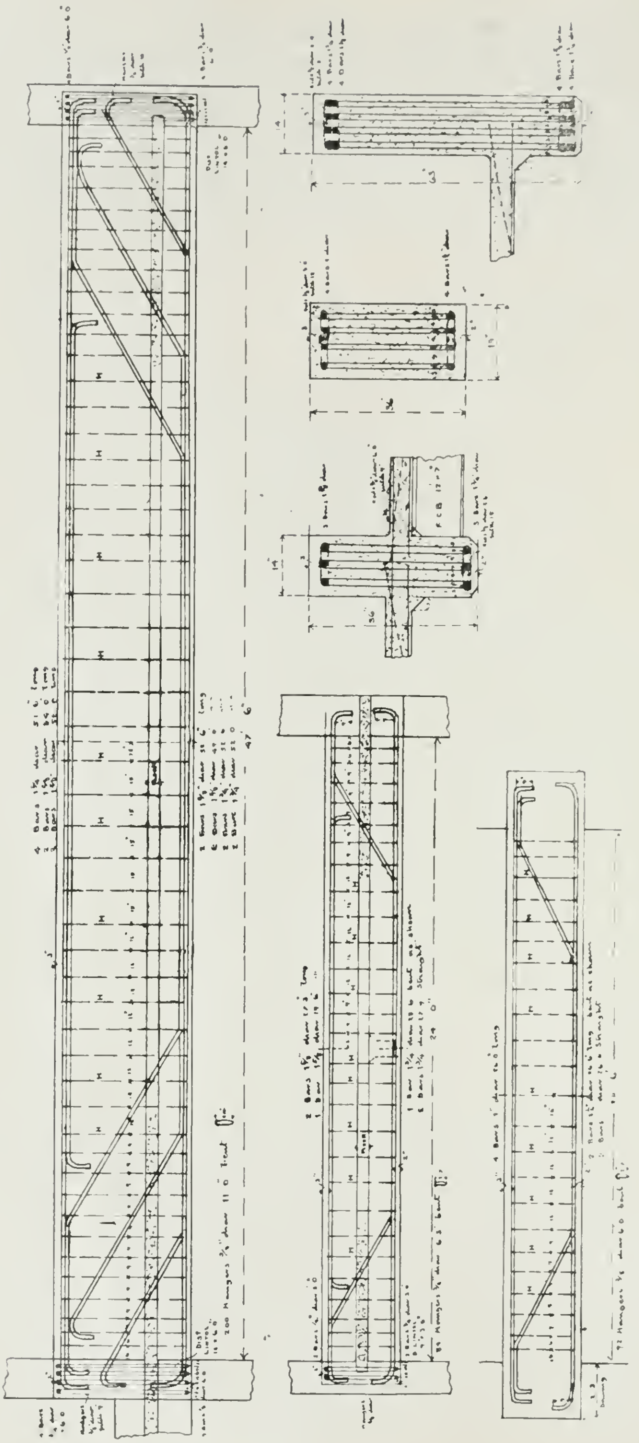


Fig. 4. Typical Beam Details.
Canterbury Theatre.

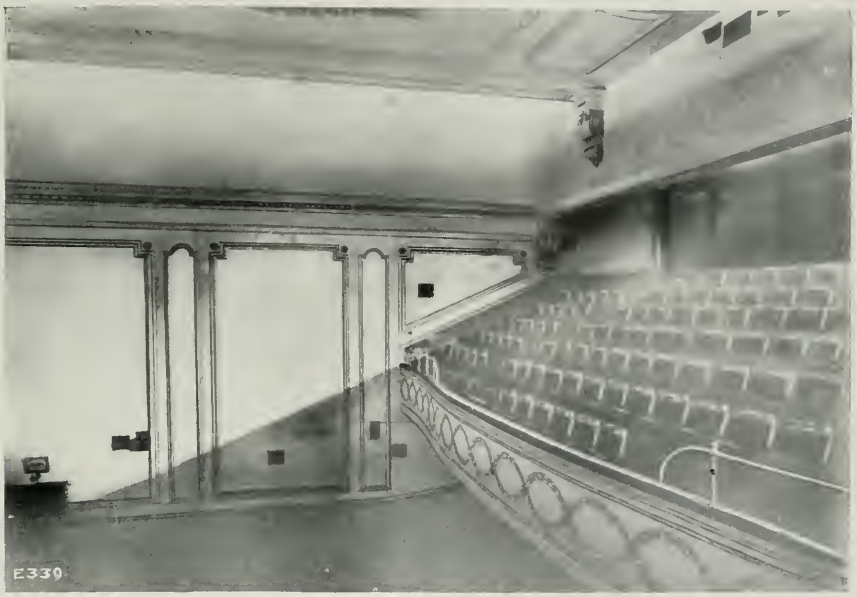


Fig. 5. Interior View.

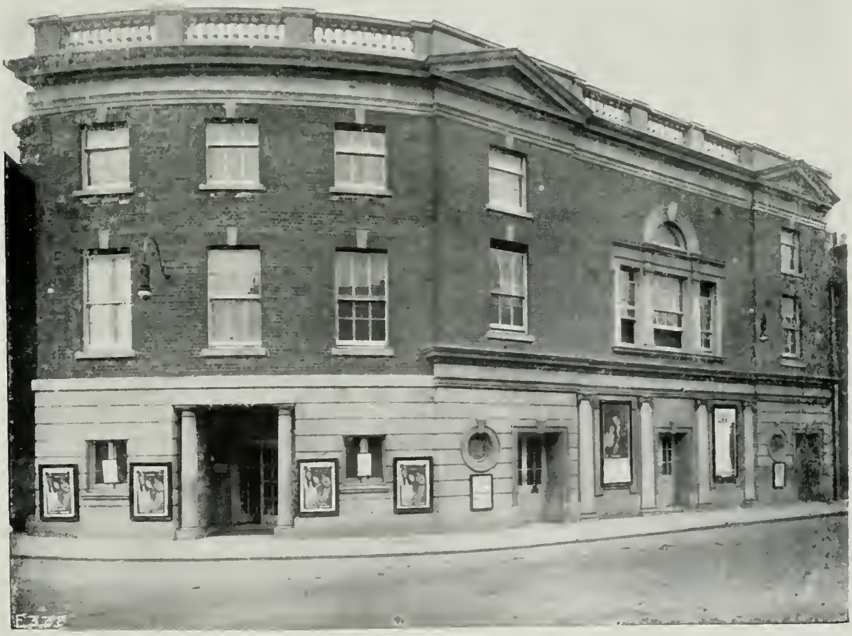


Fig. 6. Exterior View.
CANTERBURY THEATRE.

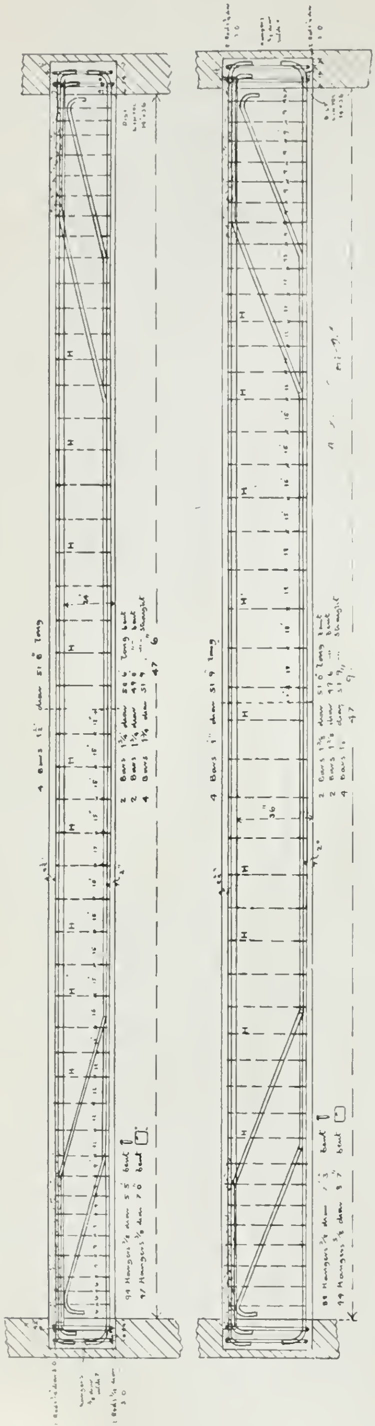

4 Bars 1½" dia 51' 6" long
2 Bars 1⅜ dia 50' 6" long bent
2 Bars 1⅜ dia 49' 6" bent
4 Bars 1⅜ dia 51' 9" straight
47' 6"
4 Bars 1" dia 51' 9" long

Fig 57. Reinforced Concrete Beams.
Canterbury Theatre.

at intervals of 18 in. throughout the length. The floor itself is constructed with 6 in. of concrete reinforced with ½ in. diameter rods, and the flat roof is formed with 5 in. of concrete reinforced with ⅜ in. rods. One beam occurs under the flat, this being 12 in. by 7 in., and having a span of 15 ft. This beam is designed as a tee beam, and ⅜ in. diameter rods are placed in the top surface of the flange at 5½ in. centres; while two 1⅛ in. diameter rods are provided as main reinforcement in the lower surface. The ends of this beam and also the one previously mentioned have reinforced concrete distributing lintels or templates at the ends when bearing on the brick walls.

The balcony over the auditorium has a projection of 24 ft. 6 in. from the main wall, with a level gangway 8 ft. wide at the top of the sloping portion. It is constructed with sloping concrete 7 in. thick, carried by three beams which span the clear width of the auditorium, a distance of 47 ft. 9 in., the front beam being kept back 5 ft. from edge of balcony, the overhang being carried by reinforced concrete cantilevers. This cantilevered portion has a maximum thickness of 1 ft. 5 in., decreased to 6 in. at the extreme outer edge, and it is reinforced with bars at 3-in. pitch in the upper and lower surfaces, these bars being in one length and bent round another bar at the outer edge which runs parallel to the edge. Distribution bars ¼ in. in diameter are also provided in both surfaces at right angles to the main reinforcement. The fulcrum beam from which this cantilevered portion springs is 39 in. deep and 15 in. wide, with eight rods in the lower surface and four in the upper. The two beams which occur under the sloping portion are 5 ft. 3 in. apart, and they are 36 in. deep and 15 in. wide, with eight bars in the lower surface and four in the upper. Where the ends rest on the brick walls special bearing portions are provided, these consisting of forming a reinforced concrete block 36 in. wide and 14 in. thick at the same time as the beam itself is concreted. The slabs are reinforced in the lower surface in both directions with rods in the upper surface over the beams, and the necessary stepping for the seats was constructed with breeze concrete. The concrete for the slabs and beams was gauged in the proportion of 4 to 1.

The floor over the balcony is 6 in. thick, and the back edge of the floor slab and the 14 in. brick wall which occurs here are carried by a reinforced beam 5 ft. 3 in. deep and 14 in. wide. This beam has a clear span of 47 ft. 6 in., and the calculated distributed load carried is 98 tons, caused by the wall, floor, and roof over. The beam was economically designed by keeping it up above the floor for a distance of 3 ft. 6 in., as seen in *Fig.* 4, and the reinforcement consists of eight bars in both upper and lower surfaces, with vertical stirrups and horizontal binding to both sets of rods. On the same illustration the beam over the stage opening is also shown, this having a clear span of 20 ft. 6 in., with a depth of 36 in. and a width of 18 in., and four rods in each surface as reinforcement. The roof over the stage is constructed with 4-in. slabs carried by tee beams at about 8 ft. 6 in. centres, the latter being 12 in. deep and having a rib 7 in. thick, reinforced with two $\frac{3}{8}$-in. diameter rods. Various other roofs are constructed in reinforced concrete, and, as previously mentioned, the whole of the staircases are carried out with this material.

The work has stood in an excellent manner, and the balcony, which was designed to carry a superimposed load of 1 cwt. per ft. super, has been tested up to the full limit, if not over, without any defect occurring. The building forms a good example of a composite structure of brickwork and reinforced concrete with no isolated interior supports, which would be objectionable in the erection of a theatre.

The contractor for the building was Mr. George Browning, builder, Canterbury.

PROBLEMS IN THE THEORY OF CONSTRUCTION.

BENDING AND TWISTING MOMENTS IN BEAMS CURVED IN PLAN.

By EWART S. ANDREWS, B.Sc.Eng.

The following article deals with an important point in construction, and will no doubt be of considerable interest to our readers.—ED.

In the design of beams curved in plan such as occur in theatre steelwork and triangular-site buildings—such as the *Morning Post* building—the beams are subjected to a twisting as well as to a bending action, and it has been in the past a matter of very considerable difficulty to calculate the resulting stresses. The subject has recently been treated* very thoroughly by Professor Gibson and Mr. E. G. Ritchie, of University College, Dundee. The difficulties of the subject are two-fold; we have first to find the bending and twisting moments which arise, and having found these we have to find the resulting torsional stresses for the beam sections to which the ordinary torsion formulæ are inapplicable.

In the present article we will deal only with the determination of the bending and twisting moments, and will, in view of the mathematical nature of the problem involved, explain the underlying principles and two of the simplest cases at greater length than Messrs. Gibson and Ritchie, in order to assist those engineers who do not take readily to purely mathematical analysis to follow these authors' work more readily.

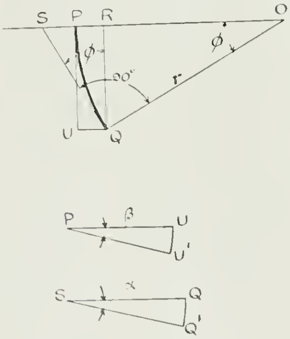


FIG. 1.

Slope of a circular arc due to bending and twisting.—Suppose that PQ, *Fig.* 1, is an arc of a beam curved in plan, the centre of the arc being at O and the radius being r. Let the arc at P be given by a bending action a small slope β in a direction below the plane of the paper; then the whole may be considered as turning about the line OP and U and Q both fall by an amount $UU' = PU.\beta = RQ.\beta = QQ'$.

$\therefore$ Slope of tangent QS at Q becomes $\alpha = \dfrac{QQ'}{SQ} = \dfrac{RQ.\beta}{RQ \sec\phi} = \beta\cos\phi$

Next suppose that P is given a small angular twist γ downwards, *Fig.* 2, then we may consider the whole as turning about the tangent PT, so that R and Q drop an equal amount $RR' = QQ' = PR\gamma$.

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* *The Circular-arc Bow-girder* (Constable). Price 10/6 net.

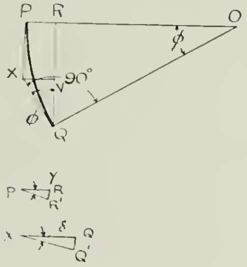

FIG. 2.

The slope δ of the tangent at Q is given by

$$\delta = \frac{QQ'}{XQ} = \frac{PR.\gamma}{XV\cos ec\phi} = \frac{XV.\gamma}{XV\cos ec\phi} = \gamma\sin\phi$$

$\therefore$ Total slope of tangent at Q due to combined bending and twisting actions $= \beta\cos\phi + \gamma\sin\phi$. (1)

Now, if we consider two points close together on the beam at a distance δs apart on either side of P, *Fig.* 3, and the bending and twisting moments over this short length are B and T respectively. Then by the well-known rules of bending and torsion, inclination at P due to bending $= \dfrac{B.\delta s}{EI}$ and due to torsion $= \dfrac{T.\delta s}{GI_P}$.

In these formulæ E and G are Young's and Rigidity moduli, and I and I_p are the ordinary and polar moments of inertia of the beam section.

By equation (1) these will cause at Q a slope equal to $\dfrac{B\delta s}{EI}\cos\phi + \dfrac{T\delta s}{GI_P}\sin\phi$

$\therefore$ If the end A is fixed so that the slope of the beam does not change there we have :—

Resulting change of slope at Q, due to bending and twisting from A to $Q =$

$$\sum_{A}^{Q}\frac{B\delta s}{EI}\cos\phi + \sum_{A}^{Q}\frac{T\delta s}{GI_P}.\sin\phi. \qquad (2)$$

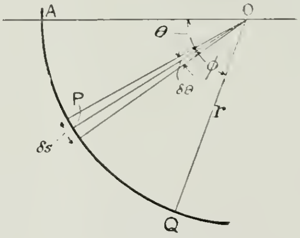

FIG. 3.

It will be seen that the present problem is similar to the case of the straight beam with fixed ends, additional difficulty arising due to the twisting action brought about by the curving of the beam.

We will now apply these results to two of the simplest special cases.

Horizontal semi-circular beam with central load.—If ACB, *Fig.* 4, is the beam, and the end bending and twisting moments are $B_A\ B_B$ and $T_A\ T_B$ respectively, and the reactions are $R_A\ R_B$, we have by symmetry :

$$B_A = B_B = \frac{Wr}{2}$$

$$T_A = T_B$$

$$R_A = R_B = \frac{W}{2}$$

Consider any point P between A and C. The bending moments there are found by considering the moments about the vertical plane through OP of the forces between A and P. We then have :

$$\text{B.M. due to reaction } R_A = R_A\,.\,AE = \frac{W}{2}r\sin\theta.$$

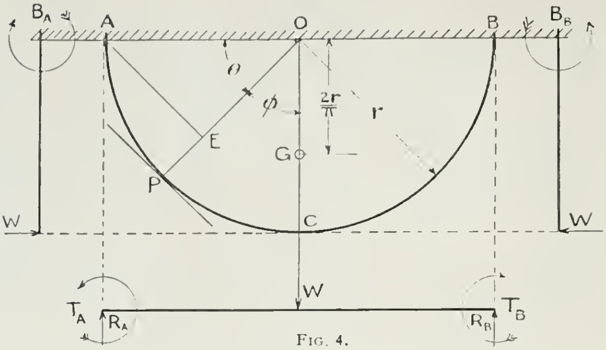

FIG. 4.

B.M. due to end B.M. B_A $= -B_A \cos\theta = -\frac{Wr}{2}\cos\theta$

B.M. due to end T.M. $T_A = -T_A \sin\theta$

$$\therefore \quad B_P = \frac{Wr \sin\theta}{2} - \frac{Wr\cos\theta}{2} - T_A \sin\theta$$

$$= \frac{Wr}{2}(\sin\theta - \cos\theta) - T_A \sin\theta \qquad (3)$$

Similarly considering twisting moments at P we have :—

$$\text{T.M. due to reaction } R_A = -R_A \cdot PE = -\frac{Wr}{2}(1-\cos\theta)$$

$$\text{,, \quad ,, \quad end B.M. } B_A = B_A \sin\theta = \frac{Wr}{2}\sin\theta$$

$$\text{,, \quad ,, \quad ,, T.M. } T_A = T_A \cos\theta = -T_A \cos\theta$$

$$\therefore \quad T_P = \frac{Wr}{2}\left(\sin\theta + \cos\theta - 1\right) - T_A \cos\theta \qquad (4)$$

$$\therefore \text{ Slope at } C = \sum_A^C \frac{M_P \,.\, \delta s \cos\phi}{EI} + \sum_A^C \frac{I}{GI_P} \,.\, \delta s \,.\, \sin\phi$$

In this case the summation can be effected mathematically by means of the integral calculus, and noting that $\delta s = r\,\delta\theta$ and that $\cos\phi = \sin\theta$ and $\sin\phi = \cos\theta$, we have, if the section remains constant,

$$\text{Slope at } C = \frac{r}{EI}\int_0^{\frac{\pi}{2}} \left\{\frac{Wr}{2}(\sin\theta - \cos\theta) - T_A \sin\theta\right\} \sin\theta \, d\theta$$

$$+ \frac{r}{GI_P}\int_0^{\frac{\pi}{2}} \left\{\frac{Wr}{2}(\sin\theta + \cos\theta - 1) - T_A \cos\theta\right\} \cos\theta \, d\theta \qquad (5)$$

$$\text{The first integral} = \left(\frac{Wr}{2} - T_A\right)\int^{\pi} \sin^2\theta \, d\theta - \frac{Wr}{2}\int_0^{\frac{\pi}{2}} \sin\theta\cos\theta \, d\theta$$

$$= \left(\frac{Wr}{2} - T_A\right)\int_0^{\frac{\pi}{2}} \left(\frac{1-\cos 2\theta}{2}\right) d\theta - \frac{Wr}{2}\int_0^{\frac{\pi}{2}} \sin\theta \, d\sin\theta$$

$$= \left[\left(\frac{Wr}{2} - T_A\right)\left(\frac{\theta}{2} - \frac{\sin 2\theta}{4}\right) - \frac{Wr \sin 2\theta}{4}\right]_0^{\frac{\pi}{2}}$$

$$= \tfrac{1}{4}\left[Wr\left(\frac{\pi}{2} - 1\right) - \pi T_A\right] \qquad (6)$$

The second integral $=$

$$\int_0^{\frac{\pi}{2}} \left(\frac{Wr}{2} - T_A\right)\cos^2\theta \, d\theta + \int_0^{\frac{\pi}{2}} \frac{Wr}{2}\sin\theta\cos\theta \, d\theta - \int_0^{\frac{\pi}{2}} \frac{Wr}{2}\cos\theta \, d\theta$$

$$=\left[\left(\frac{Wr}{2}-T_A\right)\left(\frac{\theta}{2}+\frac{\sin 2\theta}{4}\right)+\frac{Wr}{4}\sin^2\theta-\frac{Wr}{2}\sin\theta\right]_0^{\frac{\pi}{2}}$$

$$=\left[\left(\frac{Wr}{2}-T_A\right)\frac{\pi}{4}+\frac{Wr}{4}-\frac{Wr}{2}\right]$$

$$=\tfrac{1}{4}\left[Wr\left(\frac{\pi}{2}-1\right)-\pi T_A\right] \qquad (7)$$

Therefore equation (5) becomes

Slope at C $$=\frac{r}{4}\left(\frac{1}{EI}+\frac{1}{GI_P}\right)\left[Wr\left(\frac{\pi}{2}-1\right)-\pi T_A\right] \qquad (8)$$

But from consideration of symmetry, the slope of the beam at the centre C must be zero.

$$\therefore\ Wr\left(\frac{\pi}{2}-1\right)-\pi T_A=0$$

$$i.e.,\ T_A=\frac{Wr\left(\frac{\pi}{2}-1\right)}{\pi}=\cdot 182\ Wr \qquad (9)$$

At the centre C, equations (3) and (4) give $B_C=\frac{Wr}{2}-T_A=\cdot 318\ Wr$, $T_C=0$.

At the centre, therefore, the beam must be able to carry a bending moment equal to ·318 Wr, and at the ends it must carry a bending moment equal to ·5 Wr, as well as a twisting moment equal to ·182 Wr.

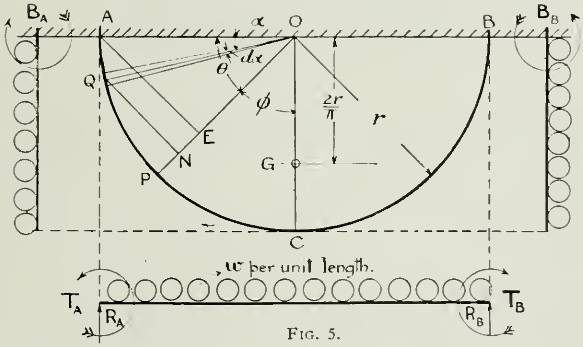

FIG. 5.

Horizontal Semi-circular Beam with Uniformly Distributed Load.— Next consider the case, *Fig.* 5, in which a horizontal semi-circular beam carries a uniformly distributed load of intensity w.

Consider an elementary length at Q subtending an angle $d\alpha$ at the centre.

Then $B.M.$ at P due to weight on element $QQ'=w\ .\ rd\alpha\times QN$

$$=wrd\alpha\ .\ r\sin\alpha$$

$$=wr^2\sin\alpha\,d\alpha$$

$\therefore$ B_P due to the weight on the beam from A to P

$$=wr^2\int_0^\theta \sin\alpha\,d\alpha$$

$$=wr^2\Big[-\cos\alpha\Big]_0^\theta$$

$$=wr^2(1-\cos\theta) \qquad (10)$$

$T.M.$ at P due to weight on element at $Q=w\ .\ rd\alpha\times PN$

$$=wr^2(1-\cos\alpha)\,d\alpha$$

$\therefore$ T_P due to the weight on the beam from A to P

$$= wr^2\int_0^{\theta}(1-\cos\alpha)\,d\alpha$$

$$= wr^2\Big[\alpha - \sin\alpha\Big]_0^{\theta}$$

$$= wr^2(\theta - \sin\theta) \qquad (11)$$

The centre of gravity of the load acts at G.

$$\therefore\ B_A = B_B = \frac{W\,.\,GO}{2} = \frac{\pi r w}{2}\,.\,\frac{2r}{\pi} = wr^2$$

$$R_A = R_B = \frac{W}{2} = \frac{w\pi r}{2}.$$

Then corresponding to equation (3) we shall have, allowing by equations (10) and (11) above, for the load between A and P

$$B_P = w\,.\,\frac{\pi r}{2}\,.\,r\sin\theta - wr^2(1-\cos\theta) - B_A\cos\theta - T_A\sin\theta$$

$$= wr^2\left\{\frac{\pi\sin\theta}{2} - (1-\cos\theta) - \cos\theta\right\} - T_A\sin\theta$$

$$= wr^2\left(\frac{\pi\sin\theta}{2} - 1\right) - T_A\sin\theta \qquad (12)$$

Corresponding to equation (4) we shall have:

$$T_P = -w\pi r^2(1-\cos\theta) + wr^2(\theta - \sin\theta) - T_A\cos\theta + B_A\sin\theta$$

$$= -w\pi r^2(1-\cos\theta) + wr^2(\theta - \sin\theta) - T_A\cos\theta + wr^2\sin\theta$$

$$= wr^2\left(\frac{\pi\cos\theta}{2} - \frac{\pi}{2} + \theta\right) - T_A\cos\theta \qquad (13)$$

Then slope at $C = \dfrac{r}{EI}\displaystyle\int_0^{\frac{\pi}{2}} B_P\cos\phi\,d\theta + \dfrac{r}{GI_P}\displaystyle\int_0^{\frac{\pi}{2}} T_P\sin\phi\,d\theta$

1st Integral $= \displaystyle\int_0^{\frac{\pi}{2}}\left[wr^2\left(\frac{\pi\sin\theta}{2} - 1\right) - T_A\sin\theta\right]\sin\theta\,d\theta$

$$= \int_0^{\frac{\pi}{2}}\left(\frac{wr^2\,.\,\pi}{2} - T_A\right)\sin^2\theta\,d\theta - \int_0^{\frac{\pi}{2}} wr^2\sin\theta\,d\theta$$

$$= \left[\left(\frac{wr^2\pi}{2} - T_A\right)\left(\frac{\theta}{2} - \frac{\sin 2\theta}{4}\right) + wr^2\cos\theta\right]_0^{\frac{\pi}{2}}$$

$$= wr^2\left(\frac{\pi^2}{8} - 1\right) - \frac{\pi T_A}{4} \qquad (14)$$

2nd Integral $= \displaystyle\int_0^{\frac{\pi}{2}}\left[\left(\frac{wr^2\pi}{2} - T_A\right)\cos\theta - \frac{wr^2\pi}{2} + wr^2\theta\right]\cos\theta\,d\theta$

$$= \left(\frac{wr^2\pi}{2} - T_A\right)\int_0^{\frac{\pi}{2}}\cos^2\theta\,d\theta - \frac{wr^2\pi}{2}\int_0^{\frac{\pi}{2}}\cos\theta\,d\theta + wr^2\int_0^{\frac{\pi}{2}}\theta\cos\theta\,d\theta^{*}$$

$$= \left[\left(\frac{wr^2\pi}{2} - T_A\right)\left(\frac{\theta}{2} + \frac{\sin^2\theta}{4}\right) - \frac{wr^2\pi}{2}\sin\theta + wr^2\left(\theta\sin\theta + \cos\theta\right)\right]_0^{\frac{\pi}{2}}$$

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* Integrate by parts.

$$=\left(\frac{wr^2\pi}{2}-T_A\right)\frac{\pi}{4}-\frac{wr^2\pi}{2}+wr^2\left(\frac{\pi}{2}-1\right)$$

$$=wr^2\left(\frac{\pi^2}{8}-1\right)-\frac{\pi T_A}{4} \qquad (15)$$

$$\therefore \text{ Slope at } C=\left(\frac{r}{EI}+\frac{r}{GI_P}\right)\left(wr^2\left(\frac{\pi^2}{8}-1\right)-\frac{\pi T_A}{4}\right)$$

This again from considerations of symmetry must be zero

$$\therefore \frac{\pi T_A}{4}=wr^2\left(\frac{\pi^2}{8}-1\right)$$

$$T_A=wr^2\left(\frac{\pi}{2}-\frac{4}{\pi}\right)$$

$$=\cdot297\ wr^2 \qquad (16)$$

At the two ends, therefore, the section must be strong enough to carry a bending moment equal to $\cdot5\ wr^2$ and a twisting moment equal to $\cdot297\ wr^2$.

From equation (12) the bending moment at the centre is obtained by putting $\theta=90^\circ$,

$$i.e.,\ B_C=wr^2\left(\frac{\pi}{2}-1\right)-\cdot297\ wr^2$$

$$=\cdot274\ wr^2.$$

At this central point the twisting moment from equation (13) comes

$$T_C=wr^2\left(0-\frac{\pi}{2}+\frac{\pi}{2}\right)-T_A\,.\,0$$

$$=0.$$

The point of zero bending moment is given by putting $B_P=0$ in equation (12)

$$i.e.,\ 0=wr^2\left(\frac{\pi\sin\theta}{2}-1\right)-\cdot297\ wr^2$$

$$i.e.,\ \sin\theta\left(\frac{\pi}{2}-\cdot297\right)=1$$

$$i.e.,\ \sin\theta=\frac{1}{1\cdot274}=\cdot785$$

$$i.e.,\ \theta=52^\circ \text{ approx.}$$

There will be another point of zero twisting moment between 0 and 90° given by putting $T_P=0$ in equation (13).

$$\therefore\ 0=wr^2\left(\frac{\pi\cos\theta}{2}-\frac{\pi}{2}+\theta\right)-\cdot297\ wr^2\cos\theta$$

$$i.e.,\ \cos\theta\left(\frac{\pi}{2}-\cdot297\right)=\frac{\pi}{2}-\theta$$

$$\text{or } 1\cdot274\cos\theta=\frac{\pi}{2}-\theta$$

$\theta=23^\circ$ approx. satisfies this result.

Between $\theta=23^\circ$ and $\theta=90^\circ$ there will be a point of maximum twisting moment obtained by putting $\frac{d\,T_P}{d\,\theta}=0$ in equation (13),

$$i.e.,\ 0=wr^2\left(\frac{-\pi\sin\theta}{2}-0+1\right)\cdot297\ wr^2(-\sin\theta)$$

$$i.e., -\sin\theta\left(\frac{\pi}{2}-\cdot297\right)=-1$$

$$i.e., \sin\theta=\frac{1}{1\cdot275}=\cdot785$$

$$i.e., \theta=52^\circ \text{ approx.}$$

The point of zero bending moment, therefore, is a point as maximum twisting moment.

This maximum twisting moment is equal to

$$wr^2\left(\frac{\pi\times\cdot616}{2}-\frac{\pi}{2}+\cdot908\right)-\cdot297\,wr^2\times\cdot616$$

$$=\frac{wr^2}{8} \text{ approx.}$$

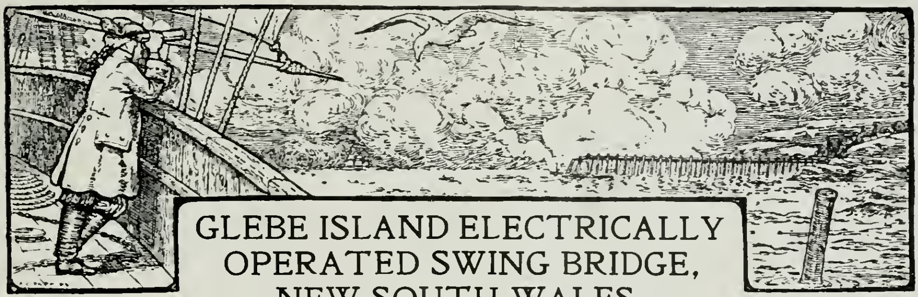
Professor Gibson and Mr. Ritchie give in their book a large number of other cases and many diagrams which engineers will find of very great assistance in the design of curved beams of this kind.

MEMORANDA.

The Institution of Municipal Engineers, Annual General Meeting.—Among the papers read at the annual general meeting of the Institution a paper was read by Mr. Horace Boot on the Manufacture of Cement, in the course of which he described the plant and the various processes through which the constituents of cement pass. He pointed out that great care has to be taken that the mixture of chalk or limestone with clay or shale is definitely and correctly proportioned. The product is ground very fine and burned at a very high temperature into the form of clinker, the temperature in rotary kilns being as much as 2,500 deg. Fahr. to 3,000 deg. Fahr. This clinker is then ground to powder, and it is usual to specify a fineness of 8 to 10 per cent. residue on a 180 by 180 sieve. The cement industry, he said, had been entirely revolutionised by the use of the rotary kiln, for labour was reduced to a minimum, and a much more uniform and even burning of the cement is possible. The result was that, for reinforced concrete work, rotary-kiln cement was nearly always specified, and would command a higher price than the other kind burned in brick kilns.

The discussion following the paper was taken part in by Mr. D. B. Butler, M.C.I., Mr. Wallin, Mr. Palmer, Mr. Cutler, and the chairman. Mr. Butler agreed that with rotary kilns it was possible to have better control over the cement than with the older type of kilns, but at the same time he pointed out that properly controlled hand-mixed cement was quite as good as that burned by the other class of kiln. Mr. Wallin said that the introduction of rotary kilns might have reduced the cost of production, but it had not reduced the cost to the user. Mr. Cutler inquired the cost per ton of producing cement at the works, and Mr. Palmer asked what was the recognised chemical composition of cement, and the difference in time in manufacturing cement by the old and by the modern method. The chairman said he always provided for the cement to be used on works of any magnitude to be tested by a recognised expert.

Concrete Flags.—At a meeting recently held of the Municipal and County Engineers it was resolved by the Standardisation Committee to recommend that an endeavour be made to arrange with the British Engineering Standards Committee for the adoption by it of a standard specification for concrete flags, and to suggest that, in the meantime, the committee adopt as a temporary measure the Institution's own standard specification for such flags.



GLEBE ISLAND ELECTRICALLY OPERATED SWING BRIDGE, NEW SOUTH WALES.

We reproduce the following interesting particulars and illustrations from the "Commonwealth Engineer."—ED.

The Glebe Island bridge crosses Johnston's Bay, an arm of Port Jackson, N.S.W., and joins Glebe Island with the mainland at Pyrmont, the swing span being provided to give access to the extensive enclosed waters of Blackwattle and Rozelle bays, where large wharfage improvements are contemplated in the near future. The electrically operated swing span weighs 650 tons, is 195 ft. 4 in. long, and affords two 60 ft. clear waterways for the passage of shipping. A 40 ft. wood-blocked roadway and two 5 ft. asphalt footpaths are provided for the heavy traffic, including a double track electric tramway which crosses the structure. The swing span, though smaller, is of similar design to the Pyrmont bridge swing span, and has been opened 63,500 times to April 30th last since the completion of the work in June, 1903. The usual time of opening or closing the span is 60 seconds, but runs of 44 seconds have been obtained. The cost of current at 1d. per b.t.u., for one complete cycle of operations, including the opening and closing of the span, the lowering and raising of the ends of the span, and the opening and closing of the four roadway gates, averages ·55 of a penny, the whole of the operations being controlled by one man from a cabin over the footpath at the centre of the span.

The bridge is flanked on either side by two immense stone causeways, 70 ft. high from the foundation to the road surface, with a bottom width of 70 yards, the two banks containing over 220,000 cubic yards of stone. This was obtained from Glebe Island, the necessary cutting down of the island and handy disposal of the stone having led to the adoption of the causeways in approach to the bridge. Notwithstanding the dredging of over 100,000 tons of mud over-laying the hard clay bottom, a slip occurred during the construction of the Pyrmont bank, resulting in the old timber bridge being overturned. Fortunately this mishap occurred without accident in the early hours of the morning, when the bridge was free from traffic.

One of the most interesting features of the work is undoubtedly the pivot pier, the design of which was a matter of earnest consideration, due to the rock being 92 ft. below water mark. With the long arms of a heavy swing span, the ends of which obtain a maximum velocity of four miles per hour, and have only 1 in. clearance from the fixed spans, the necessity of providing an unyielding foundation can be readily understood as of vital importance.

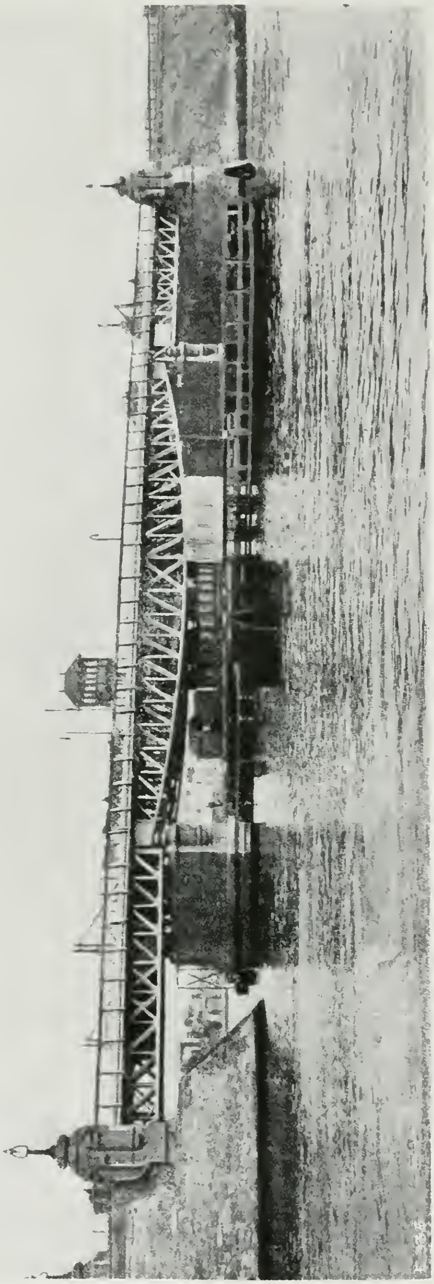


Fig. 1. View of Finished Structure.

THE GLEBE ISLAND ELECTRICALLY OPERATED SWING BRIDGE, NEW SOUTH WALES.

The site of the pier was levelled off with a ladder dredge to a depth of 35 ft. below L.W.S.T., with a resulting hard clay bottom; 97 ironbark piles were then driven 3 ft. centres with a follower to a depth of 25 ft., the bolts in slack holes connecting the follower to the permanent pile being released by a diver. The heads of permanent piles finished alternately 2 ft. and 3 ft. 6 in. above foundation level, and although rings were not used, the piles were driven without any trouble from brooming or splitting, due no doubt to the care taken in making the joint between the pile and follower. The weight on the foundation, neglecting any reduction from buoyancy, is 5,085 tons, and, assuming the whole weight to be carried by the 97 piles, the maximum load per pile would be 52 tons. The piles were driven to a test of a 20 cwt., the ram falling 10 ft., under which the penetration was not to exceed 1 in. for three blows. This penetration, with Wellington's formula, would give an ultimate supporting power of 90 tons per pile, or a factor of safety of 1·7.

The concrete octagonal base of the pier is 42 ft. over flats, so that, neglecting the supporting power of the piles and buoyancy, the pressure on the foundation would be 3·5 tons per sq. ft., as against 4 tons per sq. ft. for static loads on the London clay adopted for foundations in many large engineering works, including the Tower bridge. Although the concrete in the bases of the rest

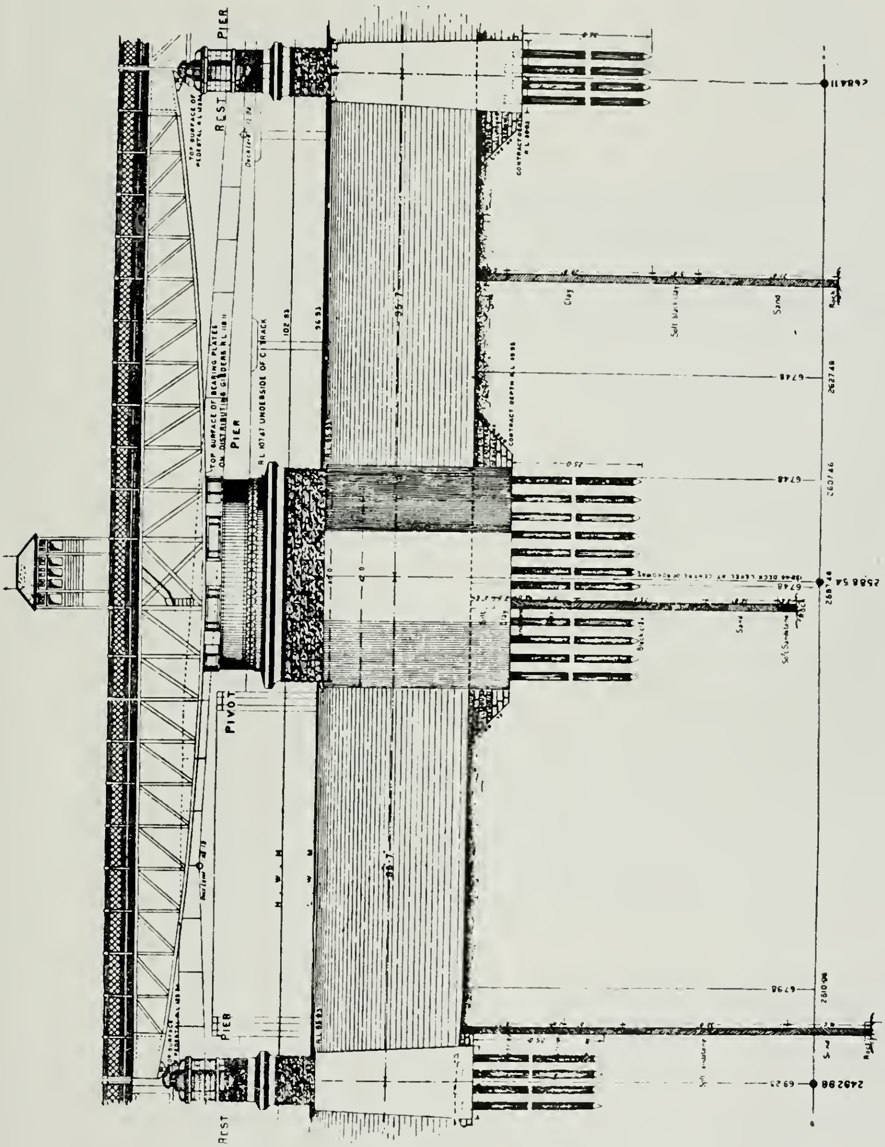

REST PIER
PIER
PIVOT
PIER
REST
TOP SURFACE OF BEARING PLATES ON DISTRIBUTING GIRDERS R.L. 111.11
R.L. 107.87 UNDERSIDE OF C.I. TRACK
Clay
Soft blue clay
Sand
Rock

Fig. 2. The Pivot Pier.

The Glebe Island Electrically Operated Swing Bridge, New South Wales.

piers at the ends of the swing span was deposited through the water in specially designed single chain self-tripping depositing boxes, the concreting being carried through continuously until completed, yet in the case of the pivot pier it was considered desirable to place the concrete in dry.

To enable the concrete in the pivot pier to be placed in dry, it was necessary to arrange for a coffer dam, which, being subject to a head of 41 ft., is understood to be one of the deepest single wall dams ever employed. The dam, which

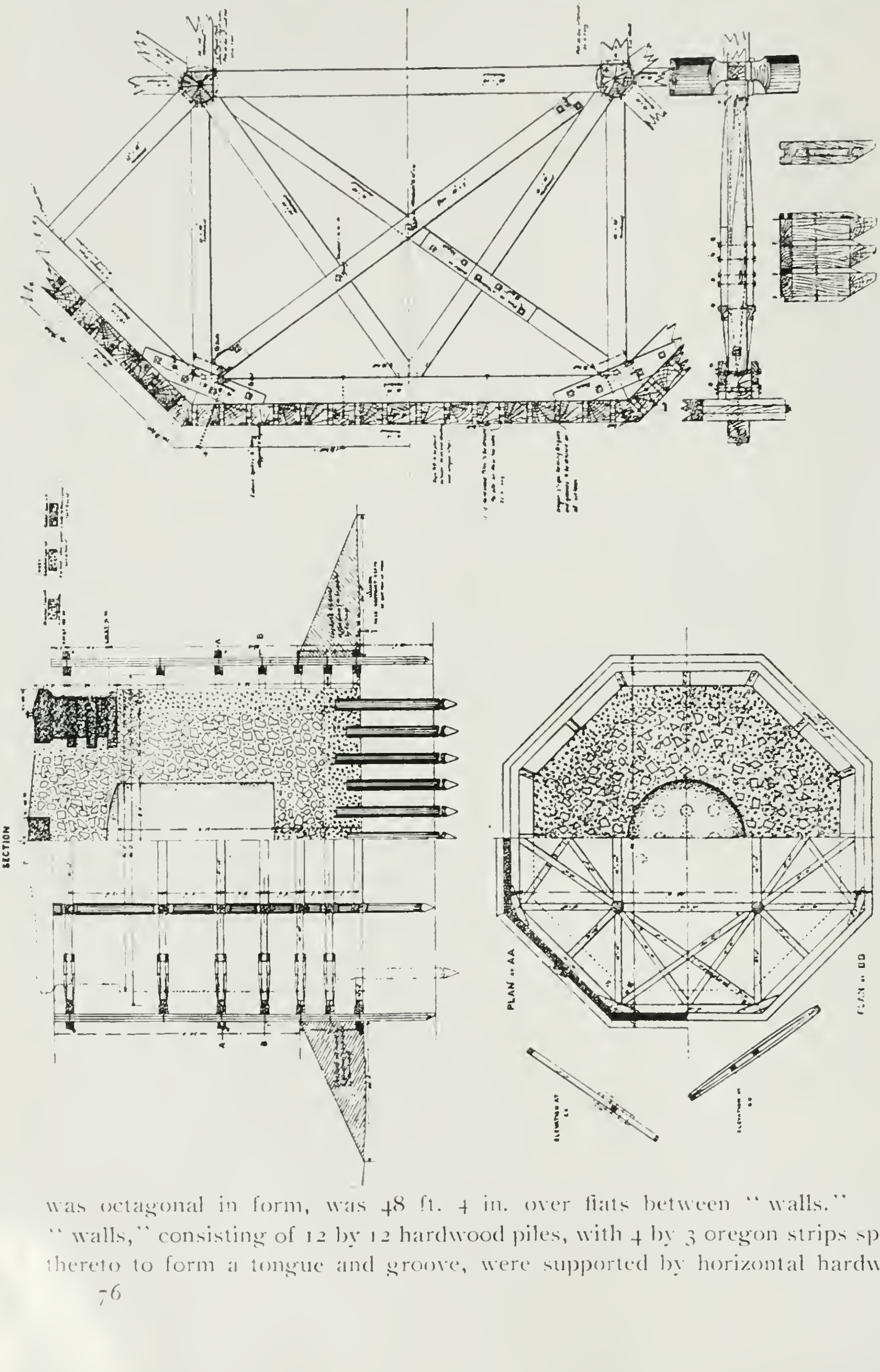


Fig. 3. Details of the Coffer Dam.

The Glebe Island Electrically Operated Swing Bridge, New South Wales.

was octagonal in form, was 48 ft. 4 in. over flats between " walls." The " walls," consisting of 12 by 12 hardwood piles, with 4 by 3 oregon strips spiked thereto to form a tongue and groove, were supported by horizontal hardwood sets placed at reducing distances apart from top to bottom, according to the increased water pressure. The hardwood timbers in each set were so arranged as to secure the counterbalancing of the resulting stresses from the water pressure on the eight sides of the dam.

By means of an octagonal frame lowered on to the bottom, and which was strutted off the foundation piles by divers, when in its correct position little difficulty was met with in driving the wall piles to correct outline. The top set having been placed in position, the remaining sets to the bottom were fixed as the water within the coffer dam was lowered by pumping. At first no impression could be made by the pumps, the water finding its way under the wall piles. Once, however, the clay round the outside of the walls had been dumped in place no further difficulty was met with, the dam being particularly tight. When the water had been pumped out the concrete surrounding the foundation piles was quickly proceeded with, the profile boards for the pier being strutted off the coffer dam walings, leaving a 2-ft. clear space for pumping out the small amount of water which leaked through the walls. Most of the water came from between high and low water mark, where, due to exposure during neap tides, the oregon strips on the piles had shrunk. The space provided between the pier and the coffer dam allowed the concrete in the pier to be set in dry, and avoided water under pressure finding its way below the foundation and passing thence through the concrete whilst green.

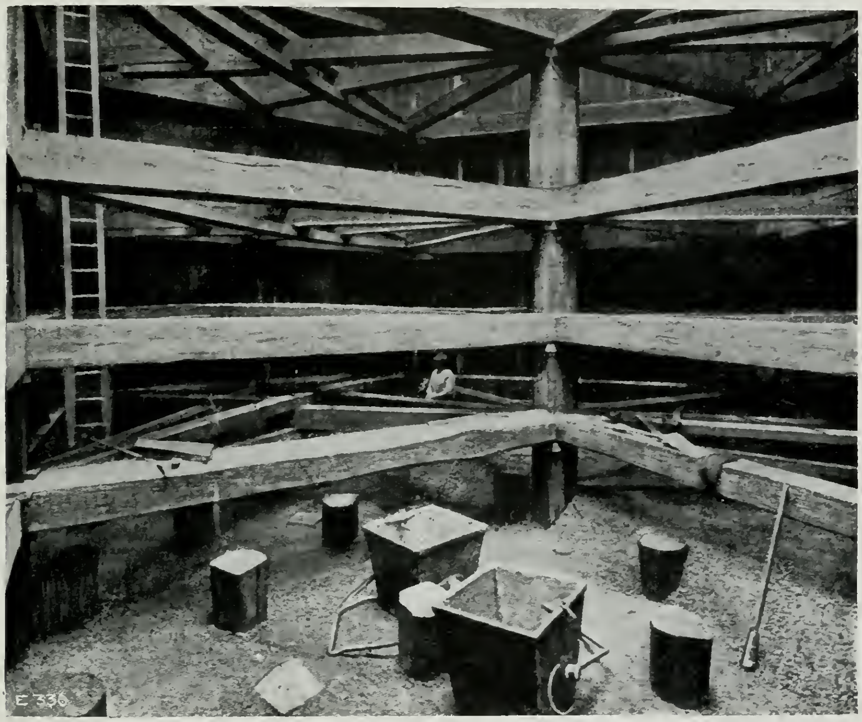


Fig. 4. Cofter Dam—Concreting Surrounding Foundation Piles.
The Glebe Island Electrically Operated Swing Bridge, New South Wales.

To reduce the amount of concrete in the pier, a large well was left in the centre. The sets were removed and the four centre piles built in as the concrete came up, the concrete being allowed to set three days before the walings of the dam were temporarily strutted off same.

The concrete octagonal base of the pier, in which large sandstone blocks up to 3 tons in weight were embedded, was finished off at 1 ft. below low water mark. The pier is 40 ft. in diameter, and is formed of rubble concrete, faced with rock-faced sandstone, and finished with a neatly chiselled, dressed stone coping.

Sixteen level points were accurately fixed on the raised portion of the coping, the intervening spaces being then worked off to a straight edge, and the whole surface rubbed down to a dead level to receive the cast iron track, which was bedded hard on the masonry.

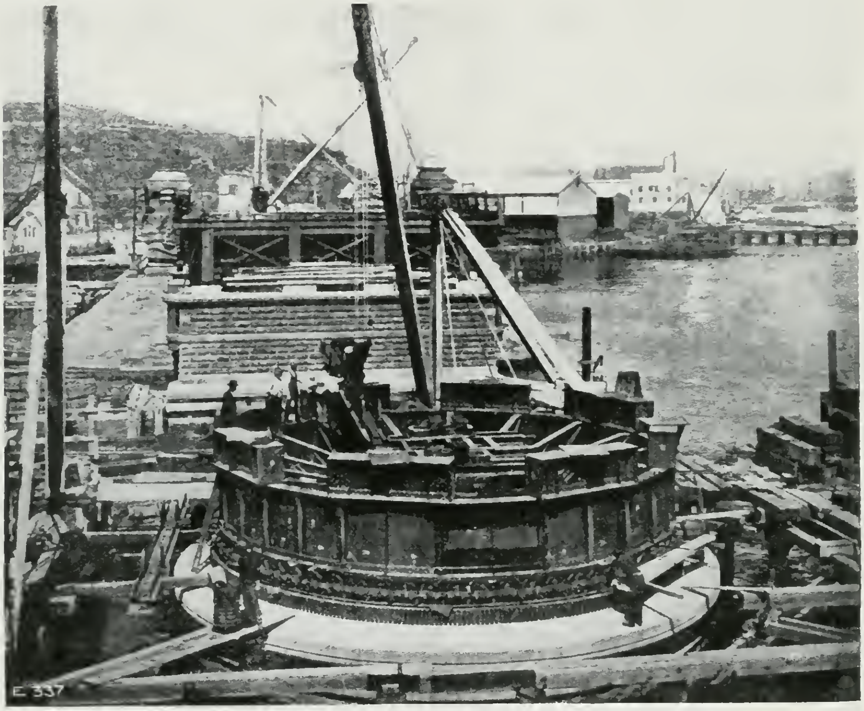
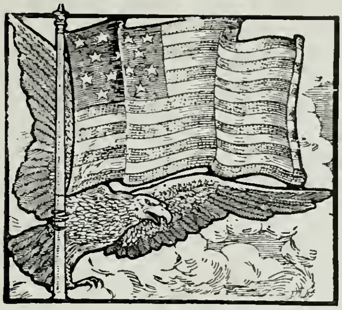


Fig. 5. Pivot Pier with Track and Turntable in position.
THE GLEBE ISLAND ELECTRICALLY OPERATED SWING BRIDGE, NEW SOUTH WALES.

The greatest care was taken in this portion of the work, as any inaccuracy would have been multiplied at the ends of the span, where only an inch vertical clearance was available. Most gratifying results were obtained, it being possible to end to end the span whilst giving the required clearance. To avoid any disturbance of the foundation, the piles forming the walls of the coffer dam were, upon the completion of the pier, cut off a few feet above the bed of clay.



THE INFLUENCE OF TEMPERATURE ON THE STRENGTH OF CONCRETE.

By A. B. McDANIEL.

We give below a short abstract from a Bulletin issued by the University of Illinois (No. 81).—ED.

MATERIALS, FORM OF TEST PIECES, AND METHODS OF STORING AND TESTING.

4. *Materials.*—The materials were of the same character and quality as those used for other concrete and reinforced concrete specimens made and tested by the Engineering Experiment Station during the past five years. The quality of the materials may be taken as representative of that used in first-class concrete work in the Middle West.

Cement. All of the test specimens were made with Universal Portland cement. Samples were taken at the beginning of each series and were tested for fineness, soundness, and tensile strength. The cement passed the requirements of the Standard Specifications of the American Society for Testing Materials. The tensile strength tests of neat and 1 : 3 mortar briquettes made of a sample of the cement used in Group III. of the 1914 Series gave average values of 542 and 609 lb. per sq. in. for the neat cement at seven and twenty-eight days respectively; and 174 and 295 lb. per sq. in. for the 1 : 3 mortar at seven and twenty-eight days respectively.

Sand. The sand used came from a deposit of glacial drift near the Wabash River at Attica, Indiana. The sand was clean and well graded. The sand of the 1913 Series was somewhat coarser than that of the 1914 lot. The sand used in Group III.—1914 Series—gave a density of 1·79, a specific gravity of 2·65, and contained 32 per cent. voids.

Stone. The crushed limestone came from Kankakee, Illinois. The stone used in the 1913 Series contained 87 per cent. material smaller than ½ in. and 46 per cent. material smaller than ¼ in. The stone used in the 1914 Series was well graded. It contained 49 per cent. voids, and had a density of 1·35 and a specific gravity of 2·65. It was carefully screened over a ¼-in. screen before use, and contained 10 per cent. of material smaller than ¼ in.

5. *Concrete.*—All the concrete was composed of 1 part cement, 2 parts sand, and 4 parts broken stone, by weight; corresponding to 1 part cement, 2·2 parts sand, and 3·6 parts broken stone, by volume. The materials for each specimen were weighed out separately and then mixed.

The mixing of the concrete for the 1913 Series was done with a trowel in a large galvanised iron pan. The cement and sand were first mixed dry to a uniform colour and spread out in a layer of uniform thickness over the bottom

TABLE 1.—Description of Test Specimens.

Series.	Group.	Set.	Specimens.		Number and Age of Specimens when Tested.
			Number.	Form.	
1913	I	A B C	15 15 15	6 × 6-in. cylinders	5 specimens of each set ; at 7, 14, and 28 days.
1913	II	D E F	15 18 18	6-in. cubes	3 specimens of each set ; at 4, 7, 11, 14, and 28 days.
1914	III	G H I M	15 15 15 15	8 × 16-in. cylinders	3 specimens of each set ; at 3, 7, 10, 14, and 28 days.

of the pan. The stone was then added, and the whole mass given four complete turnings, which secured thorough incorporation of the dry materials. Water was added, and the material turned until thoroughly mixed. The concrete was gathered together in a compact mass, in one end of the mixing pan, so as to reduce evaporation losses to a minimum. The time of mixing of each specimen was kept as nearly constant as possible.

The concrete used in the 1914 Series was mixed in similar manner to that of the 1913 Series, but was mixed on the concrete floor of the laboratory with shovels.

6. *Moulding and Storage of Test Specimens.*—The specimens were classified according to the form of test specimen and storage conditions. Table 1 gives the details of the classification.

TABLE 2.—Data Concerning Moulding of Specimens.

Type of Specimen.	Set.	Average Time of Moulding.	Average Temperature.		Weights of Materials.			Water. per Cent.*
			Air.	Concrete.	Cement.	Sand.	Stone.	
		Minutes.	Fah.	Fah.	lb.	lb.	lb.	
6-in. cylinders	A B C	8·5 8·5 8·5	32° 65° 84°	70° 71° 70°	2·17 2·17 2·17	4·34 4·34 4·34	8·68 8·68 8·68	10·0 10·0 10·0
6-in. cubes	D E F	7·0 7·0 7·0	77° 75° 71°	70° 70° 69°	2·42 2·42 2·42	4·84 4·84 4·84	9·68 9·68 9·68	10·0 11·0 10·0
8 × 16-in. cylinders	G H I M	—	68°	69°	10·2	20·4	40·8	9·3

* The concrete used in Groups I. and II. was of a medium or quaking consistency ; while that used in Group III. was wet, and was similar in consistency to that used in concrete building construction.

Moulding. The specimens of Group I. of the 1913 Series were moulded in the storage rooms under the following temperatures : Set A at 32° F., Set B at 65° F., and Set C at 84° F. The specimens of Group II. of the 1913 Series were moulded in the cement laboratory at the following temperatures : Set D at 77° F., Set E at 75° F., and Set F at 71° F. The specimens of

Group III.—1914 Series—were moulded in the concrete room of the Engineering Experiment Station at a temperature of 68° F. The specimens of Group II. and Group III. were moved to their respective storage rooms after a set of six hours.

The forms used for Group I. were sheet-iron cylinders 6 in. in diameter and 6 in. high. The specimens of Group II. were moulded in three-gang cube forms made up of two 6-in. channels and plates placed 6 in. apart. The forms for the specimens of Group III. were sections of standard 8-in. wrought iron pipe, 16 in. long. The forms were removed from the specimens after a storage of two days.

Table 2 shows the weight of the dry materials, the per cent. of water in terms of the total dry materials, the temperature of the room and of the concrete, and the average time of moulding.

Storage. The temperature of the storage room was determined by daily readings of the maximum and minimum thermometers.

Set A was stored in the ice-storage room of the Smith Ice Company in Urbana, at an average temperature of 30° F. Set B was stored in the meat storage room of the Smith Ice Company in Urbana, at an average temperature of 48·5° F. Set C was stored in the cement laboratory of the University of Illinois at an average temperature of 72·8° F.

Set D was stored in the cement laboratory of the University of Illinois at an average temperature of 68° F. Set E was stored in the ice chest of the Dairy Department of the University of Illinois at an average temperature of 35·5° F. Set F was stored in the ice-storage room of the Twin City Ice and Cold Storage Company of Champaign, at an average temperature of 27·1° F.

Set G was stored in the ice-storage room of the Twin City Ice and Cold Storage Company at Champaign, at an average temperature of 26·5° F. Set H was stored in the ice chest of the Dairy Department of the University of Illinois at an average temperature of 34·7° F. Set I was stored in an interior heated room of the Twin City Ice and Cold Storage Company of Champaign, at an average temperature of 71·8° F. Set M was stored in a chamber of the conduit tunnel under the Floriculture building of the University of Illinois, at an average temperature of 95·6° F.

All the specimens while in storage were covered with several layers of moist sacking, which was sprinkled daily.

7. *Method of Testing.*—All the specimens of Group I. were taken from their storage places to the Laboratory of Applied Mechanics of the University of Illinois the day before they were tested. They were measured and weighed, their bearing surfaces coated with plaster of paris, and then were left in the open air of the laboratory for about twenty hours under a temperature of about 70° F.

The specimens of Group II. were tested after about one hour from the time of their removal from the storage rooms. Two specimens of Set F, designated as F_{17} and F_{18}, after being stored under an average mean daily temperature of 27·1° F. for forty-four days, were stored in the testing laboratory under an average mean daily temperature of 70° F., the former for seven days and the latter for twenty-one days. The specimens of Group III. were brought to the testing laboratory from their storage places, weighed, measured, plastered, and tested within one hour. The specimens of Set G, which were stored under freezing temperatures, were allowed to thaw out before being tested.

In the tests a spherical-seated bearing block was used.

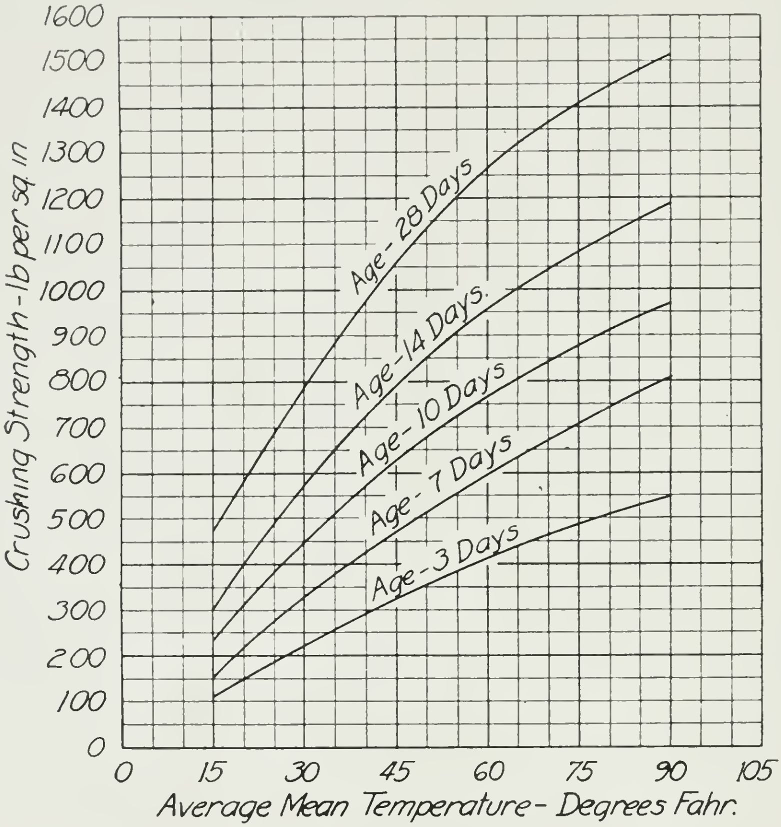


Fig. 1. Relation of Strength to Temperature for Different Ages

CONCLUSIONS.

14. *General Conclusions.*—It is believed the following general conclusions are justifiable:—

1. Under uniform temperature conditions there was an increase of strength with age within the limits of the tests. For any temperature the rate of increase decreases with the age of the specimen; and this rate of increase is less correspondingly at the lower temperature conditions. For the specimens tested, under normal hardening temperature conditions of from 60 to 70° F., the compressive strength of the concrete subjected to a uniform temperature at the ages of 7, 14, and 21 days may be taken as approximately 50 per cent.,

75 per cent., and 90 per cent. of the strength at twenty-eight days respectively. For lower temperatures the percentage values are less, and for higher temperatures the percentages are higher. The relation between the percentage values at the ages of 7, 14, 21, and 28 days is nearly the same for temperature conditions from 30° to 70° F. However, the values for the lower temperatures should be used with caution.

2. Concrete which is maintained at a temperature of 60° to 70° F. will at the age of one week have practically double the strength of the same material which is kept at a temperature of 32° to 40° F.

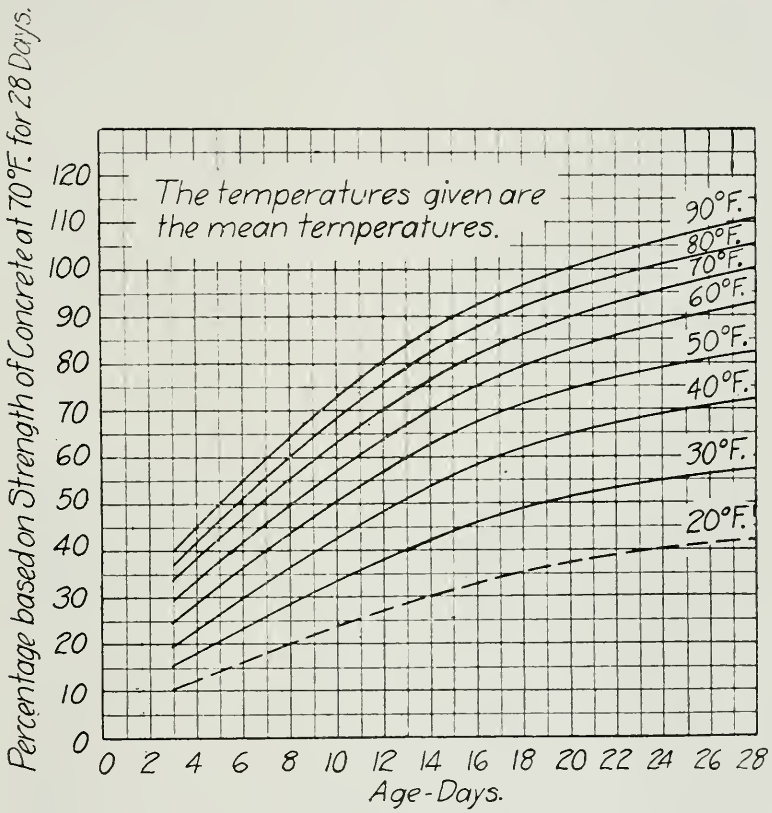


FIG. 2. PERCENTAGES OF STRENGTH FOR DIFFERENT TEMPERATURES.

3. *Figs.* 1 and 2 may be used to determine the representative strength of concrete similar to that used in these tests, for various temperature conditions and for ages up to 28 days. These diagrams may be used with a fair degree of approximation to ascertain the relative strengths which concrete of ordinary practice may be expected to attain at the different temperatures. It should be noted that generally in this investigation the specimens were stored under temperatures which were nearly uniform during the whole storage period. In Set F the variations in temperature include a number of alternations above and below the freezing point and the specimens were seriously injured. The

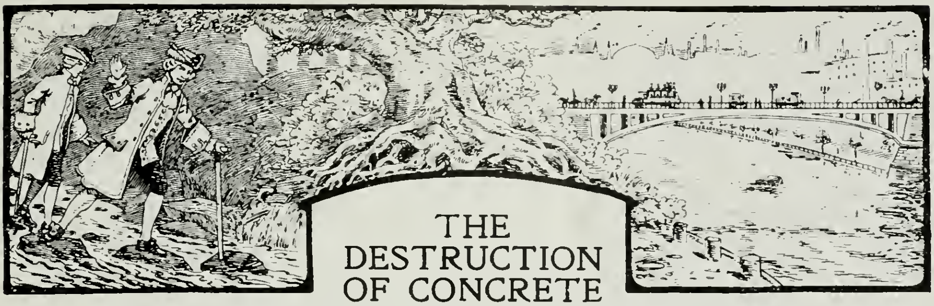
results accord with the well-known effect of freezing and thawing upon green concrete.

Acknowledgment. The tests reported herein were made in the Laboratory of Applied Mechanics of the University of Illinois. The work was done under the supervision of the writer. Special acknowledgment is due to the Department of Theoretical and Applied Mechanics for the use of material and apparatus. The writer is indebted to A. N. Talbot, Professor in Charge of Theoretical and Applied Mechanics, and to Ira O. Baker, Professor of Civil Engineering, for their co-operation in planning the tests and in interpreting the data.

MEMORANDA.

Concrete Floors for Workshops.—Concrete makes a cheap floor for a workshop, but in many cases its efficiency is often spoiled through its getting cracked after some little time, and eventually more or less broken up. As the cause of this is not generally understood, the following remarks by Mr. B. Davis, H.M. Inspector of Factories for the Kent district, may be of interest. He remarks: In addition to the obvious reason that builders often use too much sand in proportion to the cement, an insufficient thickness and bad foundations, there are others due to ignorance when the intention is good. Mixtures of sand and cement expand when they are wet, and contract as they dry, and within limits the greater the proportion of cement the greater the expansion and contraction A common practice is to put down a first layer of material with a small proportion of cement, to let this dry, and then put on top of it a thin layer with a large proportion of cement. This top part thus remains a separate layer instead of bonding with the lower part, as it would have done had it been put on at once on the still unset lower portion, while, being richer in cement, it expands and contracts more than the lower part, with the result that it may be rapidly broken up. For large surfaces, however good the work and material, the expansion and contraction is almost certain to produce cracking, unless the work is divided up vertically into sections with thin strips of wood between them.

Electric Car Heaters for Cold Weather Concreting. — The Salt Lake and Ogden Railway was able to complete over half a mile of street track last winter by heating the concrete with car heaters. The concrete was poured through chutes direct from the mixer to the track, and the heaters were then installed at intervals of 10 ft. and connected 10 in series on a 720-volt circuit, keeping the concrete warm until it had set. Canvas was stretched over the green concrete and current was taken from the trolley wire by means of a fishpole connection.—*Electrician.*



THE DESTRUCTION OF CONCRETE BRIDGES BY MEANS OF EXPLOSIVES.

In a recent number of " Beton u. Eisen " we find the following particulars on the above subject, contributed by Staff-Captain P. W. Scharros, Dutch Engineers' Instructor in the Royal Military Academy, Breda, Holland.—ED.

Whilst the destruction of concrete and reinforced concrete bridges in warfare is comparatively simple, and leads to such results as that shown in *Fig.* 1, the process in peace is complicated by the necessity of preserving the reinforcement as far as possible from injury. When this condition is fulfilled, the destruction is not more costly than that of a masonry or steel bridge. Such destruction is more and more often called for as the bridges in industrial countries become inadequate to the traffic for which they are intended.

Civil engineers have frequently used compressed air or electrically driven machinery for the purpose, being less accustomed than military engineers to the use of explosives. The author intends to show that even in civil practice the end is more readily and cheaply attained by the use of explosives, and that it is possible to preserve the reinforcement as thoroughly as when mechanical methods are used.

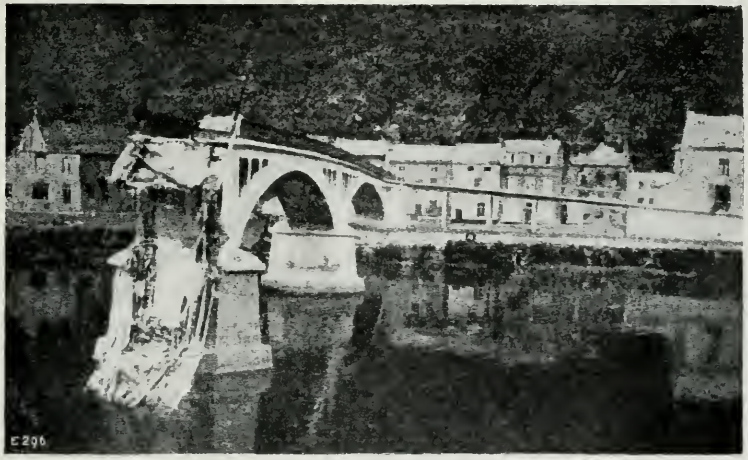


Fig. 1. Bridge over the Meuse at Dinant after Destruction.
The Destruction of Concrete Bridges by Means of Explosives.

Since concrete has only a very low tensile strength, mass concrete is very readily ruptured by the expansive force of explosives, especially of high explosives, which give rise to such intense dynamic stresses. The concrete usually breaks into a few large pieces, which may be hurled to a considerable distance. An American magazine explosion hurled masses of concrete weighing half a ton 700 metres. Mass concrete bridges are thus easily destroyed by destroying such parts of the structure as will allow the rest to collapse under ordinary static load. Thus small charges of high explosives may be fired in holes drilled in the concrete. Structures of great military importance, such as bridges and dock walls, are often provided beforehand with mine chambers and mining passages. In the second place, charges of high explosives may be fired after attachment to the outer surface of the structure. This method is rapid, but wasteful of material. It is always adopted where the structure lies under water, where the preparation of bore-holes would be too difficult.

Reinforced concrete withstands sudden tensile stresses much better. Thus all recent tunnels for testing the safety of mining explosives have been constructed in reinforced concrete. The experimental tunnel at Liévin, in France, constructed with an internal resistance of 4 kg. per sq. cm., has withstood 1,229 explosions without internal injury, whilst externally the finishing coat has been dislodged here and there.

The method to be adopted therefore involves the destruction of the concrete at statically important points, followed by the cutting of the reinforcement by explosives, sawing, or the oxy-acetylene flame. It is found that the concrete in reinforced structures is shattered into small fragments. This makes it very suitable for the construction of magazines, the danger to the surroundings being thus reduced to a minimum. The German trial ground at Kummersdorf is provided with ten explosives magazines of reinforced concrete, and the same material is used for the torpedo magazine at Den Helder, in Holland.

The preparation of bore-holes in reinforced concrete structures is usually troublesome on account of the uncertainty of the position of the reinforcement, and where mine chambers have not been provided beforehand, charges attached to the surface are mostly employed, usually in the form of several parallel lines of charge.

The following rules are in use for determining the charge :

Where numerous light charges are used, so as to secure a great effect with economy of explosive, the load L in kilograms is given by the formula

$$L = g.o.w.^3$$

where g is the charge coefficient (7 for black powder and 3 to 5 for high explosives), o is the tamping coefficient, and w the distance of the charge from the nearest surface.

Where few heavy charges are used, as when quickness is more important than economy, the formula is

$$L = g.q.o.w.^3$$

where q is a coefficient depending on the form of the crater to be produced.

Where charges attached to the surface are to be employed, the charge per metre length of the structure is

$$L = g.q.w.^2$$

Where internal charges are to be used in reinforced concrete, they may be two or three times as great as for plain concrete. The following experiments were made by the Railway Company of the Dutch Corps of Engineers in 1903.

The beams for testing were 3·75 metres long, 12·5 cm. broad, and 20 cm. high made up of 1 part Portland cement, 2 parts sand, and 3 parts gravel, and reinforced with two 19 mm. round rods in the under part and two 6 mm. rods in the upper part. The value of L in grams was found to be

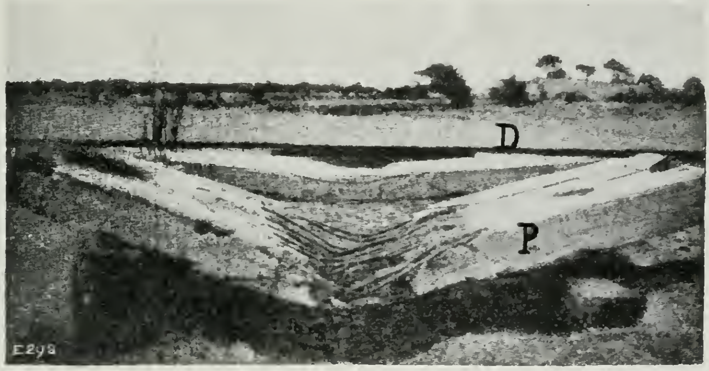


Fig. 2. A Reinforced Concrete Beam.
THE DESTRUCTION OF CONCRETE BRIDGES BY MEANS OF EXPLOSIVES.

$$L = b.h.$$

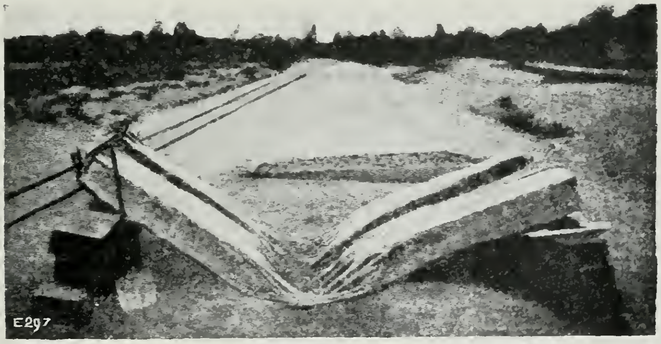


Fig. 3. Another Reinforced Concrete Beam.
THE DESTRUCTION OF CONCRETE BRIDGES BY MEANS OF EXPLOSIVES.

where b and h are the breadth and height respectively in centimetres. This is the charge necessary to separate the concrete from the steel, and holds good for all high explosives except kieselguhr-dynamite and gun-cotton.

Other beams (*Fig.* 2) were made of a mixture with 2 parts gravel instead of 3, reinforced above and below with 16 round rods of 16 mm. diameter. Such a beam (P) was shattered by two charges of picric acid of 2,400 g. each, 50 cm. apart. In the beam D two similar charges of kieselguhr-dynamite were used, with much less effect. For this explosive and gun-cotton the value of *L* must be multiplied by 1·25. The effect of more thorough tamping is seen in *Fig.* 3. (Picric acid is the explosive known as melinite in France, ecrasite in Austria, explosive 88 in Germany, and lyddite in England.)

The effect in practice is seen in *Fig.* 4. This landing stage was carried on two horizontal beams, 40 × 25 cm. Two charges were used, each of 40 × 25 = 1,000 g., 50 cm. apart, fired electrically. One of the two vertical piers, 25 × 25 cm., was also shattered by two charges each of 25 × 25 = 625 g., 50 cm. apart. The other pier was more strongly reinforced, and the charge used was half as large again, but this was quite unnecessarily large.

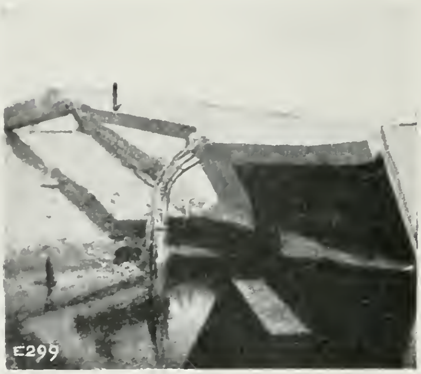
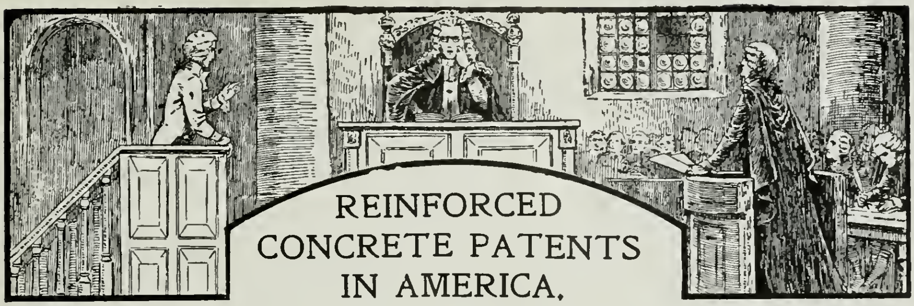


Fig. 4. A Landing Stage.
The Destruction of Concrete Bridges by Means of Explosives.

MEMORANDUM.

Cement Flood Gates.—The owners of a large natural park on Whidbey Island, in Puget Sound, have dammed up a salt-water lagoon with the aid of cement flood-gates and thus made a salt-water lake for bathing purposes for campers occupying the park. The waters of the North-West are rarely warm enough for comfortable surf bathing; but where salt water can be caught as the tide rises and fills shallow lagoons, it soon becomes heated by the sun, and thus makes bathing a real enjoyment. Also, when the outgoing tide takes the water out of the lagoon the sun quickly heats the sandy bottom. A concrete dam, with gates, built across the narrow entrance holds the water as long as it is wanted when the tide rises again. The gates are made of cement, and fit in grooves in the dam walls. They are raised and lowered by ordinary windlasses. A rustic bridge surmounts the dam, so that vehicles may pass back and forth from one side of the lagoon to the other. This scheme, which cost comparatively little, gives the owners of the park positively the finest salt water bathing pool on the Sound; and when the lagoon is filled it covers several acres. Furthermore, danger from drowning is almost wholly eliminated. The water is but neck deep, except for a pocket formed near the gates, where the racing tides have excavated a deep hole.—*The Engineer.*



REINFORCED CONCRETE PATENTS IN AMERICA.

By DOUGLAS LEECHMAN, A.I.M.E.

The decision reported below (abstracted from "Engineering News") on the validity of the Luten U.S.A. Reinforced Concrete Patents raises the interesting question as to how far invention is essential to the validity of a British patent. A sudden, bright idea may be quite enough; on the other hand, the laborious working out and application of existing knowledge may not be sufficient. The invention may lie in the creation of a desideratum which, once appreciated, may require no ingenuity to carry out. The mere application of known principles of design is not enough. Perhaps one may best state the case by saying that there must be originality, as distinct from mere novelty, to constitute good "subject matter" for a valid patent.—ED.

A PATENT case of considerable importance to those concerned in the reinforced concrete industry has been tried recently in America. Mr. Daniel B. Luten, the grantee of seven United States patents relating to arches, bridges and other reinforced structures, brought an action against George Washburn and others for the infringement of all seven patents by the construction of a little bridge of some 30-ft. span. The defendants pleaded lack of invention, anticipation by description and use and common knowledge, and they also denied infringement.

Brief particulars of six of the patents are as follows: the seventh (No. 933,771) was not proceeded with at the trial.

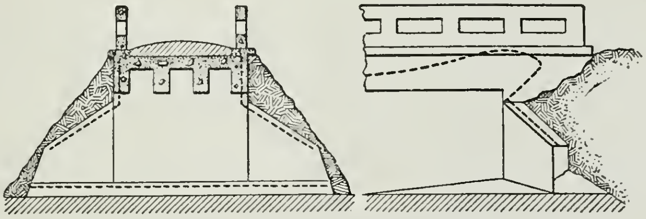


FIG. 1. ILLUSTRATING CLAIM FROM PATENT 852,970.

No. 852,970, issued May 7th, 1907, consists in the binding together of the individual wings and abutments, and of the two wings and abutments at each end of a bridge by reinforcing rods extending into and through them.

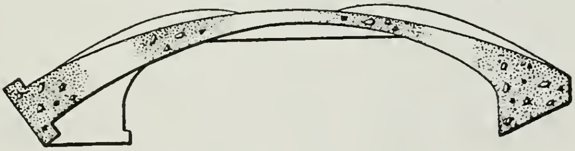


FIG. 2. ILLUSTRATING CLAIM FROM PATENT 853.183.

No. 853,183, issued May 7th, 1907: According to this specification an arched knee brace is set in the angle formed by the abutment and the outer girder of the bridge, as distinguished from the triangular knee braces under the inner girders. The bridge has two outer girders projecting above and below, and with a roadway between the upper girders and reinforcing members in the lower ribs.

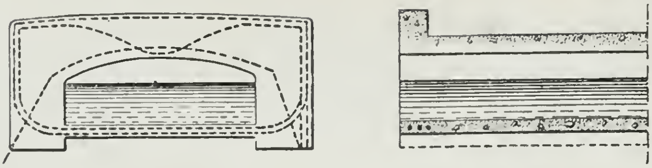


Fig. 3. Illustrating Claim from Patent 853,202.

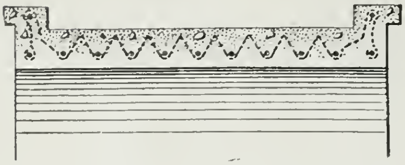


Fig. 4. Illustrating Claim from Patent 853.203.

No. 853,202, issued May 7th, 1907, relates to a bridge spandrel or retaining wall of concrete with reinforcing members near the stream and roadway surfaces, to the extension of such spandrel or girder across the abutment and cantilevered on the abutment with tension members extending across the abutment near the upper surfaces of the spandrel or girder, to longitudinal reinforcing tension members near the lower surface of said spandrel or girder, said tension members having upward extensions towards the ends of the girders, and to reinforcing tension members embedded near the lower surfaces of said spandrels or girders and having a plurality of shear members extending upwardly and inclined towards the ends of the girders, and tension members embedded near the upper surfaces of the girders and over the abutment.

No 853,203, also issued May 7th, 1907, relates to bridges in which the reinforcing members lying transverse to the roadway extend up into the wall or spandrel near its back face and overlap other reinforcing members embedded in the wall or railing.

No. 979,776, issued December 27th, 1910, relates to reinforcing members in the girders of a concrete bridge comprising a lower horizontal tension rod and upper and lower shearing rods, each having a central horizontal part, inclined parts extending outwardly from opposite ends of the central parts, and the horizontal parts extending outwardly from the ends of said inclined parts, the central horizontal part of the lower shearing rod being longer than that of the upper shearing rod, and the horizontal ends of the upper shearing rod being longer than those of the lower shearing rod.

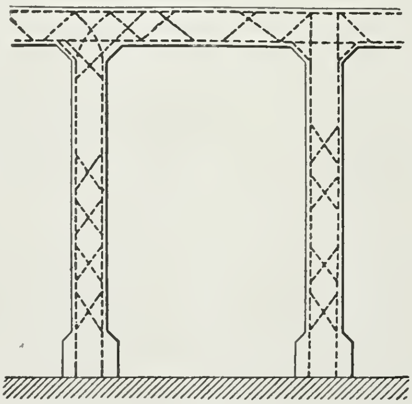


Fig. 5. Illustrating Claim from Patent 979.776.

Lastly, No. 989,272, issued April 11th, 1911, relates to embedded tension members reinforcing the concrete abutment and the outer concrete rib or girder continuously adjacent to the surfaces opposite the knee brace and extending away from such opposite surface of the transverse member between the middle and the knee brace and other tension members embedded longitudinally through the knee brace.

The case was tried in the Colorado Federal district court by Judge Lewis, who found in favour of the defendants. In his opinion all the plaintiff's alleged inventions had been anticipated. Considering the state of the art at the times in question, the plaintiff had done nothing more than apply mechanical knowledge; he had not exercised inventive skill. François Coignet, in his U.S. Patent No. 88,547 (1869), claimed: "The introduction, in the body of artificial stones, or in the body of artificial stone monolithic structures, made of agglomerated artificial stone paste, of skeletons, or metallic framework, linked or arranged so as to strengthen the same."

The patents of Hinckley, Hennebique, and others covered certain features of Luten's devices. All the plaintiff's inventions being "non-patentable," it was not necessary to consider the issue of infringement. The fact that the plaintiff had obtained judgment in fourteen other suits did not weigh with him, as none of the actions had been defended.

Whether this decision will be upheld on appeal remains to be seen.

RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers & Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE SURVEYORS' INSTITUTION.

SOME NOTES ON REINFORCED CONCRETE.

By R. M. KEARNS (Fellow).

The following is an abstract from an interesting paper read last month at the Ordinary General Meeting of the Surveyors' Institution.

Introduction.—In view of the mass of literature describing the various "systems," and of the theories and bewildering formulæ connected with stresses and strains, the subject appears to be particularly dry; but a keen interest in it may be aroused if we exercise our reflective faculties in attempting to realise all that a reinforced concrete structure represents. For instance, if we pause to inquire into the origin and supply of our building materials there is unfolded to us the enthralling epic of the soil, from which we learn that our ballast and sand (the water-worn fragments of pre-existing rocks), the mineral products from which the steel rods are made, the chalk and clay for our cement—all come to us from a far-distant past in obedience to the marvellous law of nature. We learn that the solar system itself is involved, and that from the earth's planetary relations and the concomitants of night and day, summer and winter, heat and cold, arise forces ranging from the terrible upheaval of the volcano, from earthquake and hurricane, to the soft zephyr and the gentle-flowing stream—all of which unite in the ceaseless work of modifying the earth's crust, here disintegrating, and there reassembling, reconstructing. In this connection it may be noted that in assembling our materials and forming reinforced concrete we are working on nature's lines, evolving, what is very remarkable, a rock-like composition which is reputed to be proof against the primary disintegrating forces to which I have referred—reinforced concrete, when constructed properly, being able to withstand the shock of an earthquake and all attacks from fire, wind, and water.

But we must not imagine that reinforced concrete will for ever remain untouched by the limiting hand of Time; for, according to Cowper—

> "We build with what we deem eternal rock:
> A distant age asks where the fabric stood;
> And in the dust, sifted and searched in vain,
> The undiscoverable secret sleeps."

Forms, Centering.—If we now turn our attention for a moment to the timber—in scaffolding, forms and centering—which is so much in evidence during the construction of a reinforced concrete building, a mental flight is suggested to the spruce-fir forests of northern Russia, Norway and Sweden, or North America. We may follow still further to the swirling waters, and the hum and shrieking whirr of sawmills, and then across the sea to crowded dock and contractor's yard.

Reinforcements.—Passing to the scenes in which our steel reinforcements are manufactured, we enter the murky atmosphere of coalfields and foundries. We may now conjure up some lurid pictures of swarthy workers in iron engaged on their allotted tasks, and presenting a weird and uncanny appearance as, stripped to the waist in many cases, they move to and fro in the fierce glare of furnaces and among machinery which is awe-inspiring in its power and precision.

Cement.—And what of the cement which, after all, is the most important factor in the construction of reinforced concrete? What is this wonderful material, inert in itself, but which, under the influence of water, exerts a silent and progressive force that binds ballast, sand, and steel with an interminable grip, thus forming a still more wonderful concretion? It is a fine powder known as Portland cement, so called on account of its resemblance, when employed in forming a rendered surface, to Portland stone, and is made from a mixture of chalk (or limestone), clay, and water by various processes of drying, burning, and grinding.

For a succinct and lucid definition we must, however, go to America. Mr. Jerome Cochran, in "A Treatise on Cement Specifications," gives the following:—

"Portland cement shall be defined as the finely pulverised product, resulting from the calcination to incipient fusion, of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition of other material greater than 3 per cent. has been made subsequently to calcination. No slag, pozzolana, sand, nor mixed cements, will be accepted under this classification. In other words, the cement shall be manufactured of a mixture of argillaceous and calcareous material in definite proportions, and shall contain no furnace slag, gray limestone, hydraulic lime, or trash."

Having, then, come to a clear understanding in regard to Portland cement, we may venture to recall the fact that, although it was invented in 1824, it is only after trials and experiments undergone during a period of about ninety years that it has reached its present perfect condition. It is significant that the advent of this cement, which was destined to have such a far-reaching effect on the building world, synchronises very closely with that of steam power as a means of locomotion. The evolution of Portland cement, and the displacement for building purposes of cast-iron, and then wrought-iron, in favour of steel, are, indeed, eminently associated with the phenomenal progress in applied science which took place during the Victorian era. A hundred years ago, had reinforced concrete been initiated in any reliable mode of construction, it could not have been adopted for building purposes except in a few districts; for at that time, when railways and motor lorries were non-existent, and when a system of canals was advocated for the transit of merchandise, the cost of getting the proper materials together would have been prohibitive. Now, however, owing to the economy effected in the manufacture and delivery of cement and steel by the use of steam and electric power, the adoption of reinforced concrete should come within the range of practicability, not only in the United Kingdom, but in any habitable portion of the globe where there is road or rail.

REINFORCED CONCRETE STRUCTURES.

H.M. New Stationery Office.— I now submit some notes on reinforced concrete structures, hoping that they will serve as a basis for an edifying discussion.

Starting with H.M. New Stationery Office, a building which has attracted much attention, I quote, with the kind permission of the Commissioners of H.M. Office of Works, the following extracts from the specification:—

> *River or Pit Ballast.*—To be free from sand and dust, must not contain any traces of calcareous, argillaceous, or other foreign matter, and to be broken into various sizes, so that all shall pass a ¾-in. mesh, and be retained on a ¼-in. mesh. The sand to be screened out of the ballast; all passing the ¼-in. mesh to be reckoned as sand.
>
> *Sand.*—To be freshwater, river, or pit sand, absolutely clean and sharp, properly graded and varied in size; all passing a ¼-in. mesh, and at least 75 per cent. passing an ⅛-in. mesh.
>
> *Cement.*—The cement shall be Portland (slow setting) to comply with the British Standard Specification (1910) for Portland cement. The builder is to provide with each consignment the maker's certificate of quality, but such certificate is not to be taken as conclusive. Such tests as the architect may direct will be made from time to time, and no consignment is to be used until the architect has signified his approval. The builder is to deliver consignments in advance for use, so as to permit of 28-day tests being made without causing delay in the progress of the work.
>
> *Formwork.*—The whole of the timber centering, etc., used for the formation of concrete work is to be constructed in a solid, rigid, and substantial manner. The centres

to be so formed that they may be removed in portions without shaking or jarring the concrete. To be wrought thicknessed and close-jointed, except where walls and ceilings will be plastered, and also to all external work where boarding, rough from the saw, and close-jointed, is to be used. No part of the centering is to be removed until the concrete is thoroughly set, and until the consent of the architect has been obtained. The form-work is to be thoroughly cleared of shavings and rubbish, and must be hosed out before the concrete is deposited.

Concrete.—To be made up as follows :—

Cement	1 cwt.
Sand	2 cubic feet.
Ballast	4 ,, ,,

To be sufficiently watered and mixed thoroughly, in an approved mechanical appliance, to the satisfaction of the architect. Test cubes, 6 in. by 6 in. by 6 in., of the concrete are to be mixed by the builder from time to time as the architect may direct. These cubes are to have an ultimate crushing strength of 1,800 lb. per sq. in. at 28 days. The concrete to be deposited in layers not exceeding 3 in., unless otherwise permitted by the architect, and to be properly punned and consolidated. The reinforcement to be completely surrounded and covered. No traffic on or over the concrete to be permitted until it is thoroughly set. It is to be protected from frost, inclement weather damage, or too rapid drying, and kept well wetted. No steel, except binding rods or stirrups, is to be nearer than 1½ in. to the external face of concrete, except in thin floor slabs, where the cover may be reduced to ¾ in. No concrete to be used which has been left standing and begun to set. Floors and roof to be finished smooth with a rule. The roof slabs to be laid to fall.

Granolithic Finish.—The upper ½ in. of floors (except where otherwise specified) to be formed of 1 of cement to 2 of approved granite chippings to pass a ¼-in. mesh, and to be free from dust. To be laid while the reinforced concrete is green, and to be trowelled off within an hour of laying. This surface finish to be in addition to the structural part.

Steel.—To be obtained from firms approved by the architect, and to be of such quality as to withstand the following tests : The ultimate tensile strength lengthways with the fibre is not to be less than 27 tons, and no more than 32 tons to the square in. Specimen pieces of steel are to be bent cold until the ends close over a bar, the diameter of which is the same as that of the piece to be tested. The steel rods throughout are to be of the exact lengths and diameters shown on drawings. No welding or piecing of rods will be permitted, and they are to be bent where required to templates and while cold. After such smiths' work as may be required on the rods has been completed, the steel of which they are formed must present a smooth surface free from seams, flaws, or cracks. Great care is to be exercised in the fixing and maintenance—during the placing of concrete—of the steel rods in the exact positions shown on the drawings, and in securing the links and stirrups by which the rods are to be connected together in the positions shown for them, so that the position of the reinforcement in the finished structure may exactly correspond with the position as designed.

External Finish.—Render the reinforced concrete work where exposed externally with Portland cement and sand in the proportion of 1 of cement to 3 of sand, ½ in. thick, finished with an approved floated face. The finishing coat to be applied before the backing is thoroughly set. The concrete is to be hacked to form a sufficient key for the rendering, and is to be cleaned and thoroughly wetted before the rendering is commenced.

Boiler Chimney.—To be lined to a height of 50 ft. with approved Staffordshire fire-bricks laid in fireclay, with all the joints well flushed up. To have 1½ in. air space between the firebrick and concrete, ventilated as directed. The chimney is to be built clear of the building, as shown on drawings.

Flues.—Smoke flues in chimney-breasts are to be formed of terra-cotta pipes 10 in. in diameter and with butt joints.

Bills of quantities were prepared, from which a schedule of prices was made for the adjustment of variations. The most important items were, briefly, as follow :—

Excavations from general area over site.	At different depths.	Per yard cube.
Ditto, in pier holes	,,	,,
Planking and strutting	—	Per foot super.
Ferro-concrete (steel taken separately) :—		
In footings to columns		Per yard cube.
In columns to basement and sub-ground floors		,,
In ditto to other floors (each floor kept separate)		,,
In sub-ground and ground floor, and in beams to same		,,

In other floors and in roof (each kept separate)	Per yard cube.
In external walls at various levels (one item)	,,
In internal ditto ditto (one item)	,,
In area walls	,,
In chimneys and foundation to same (one item)	,,
In bridge (one item)	,,
Steel bars prepared and hoisted (one item)	Per ton.
Formwork :—	
To columns, internal or external (one item)	Per yard super.
To floors, including beams (sides of beams, etc., not measured, but covered by price) (one item)	,,
To staircase (measured on girth of riser and soffite)	,,
To chimney	,,
To internal and external walls (one item)	,,
To bridge (one item)	,,
To retaining walls (measured both sides and on the flat)	,,
To mouldings (excepting to columns)	Per foot super.

I have omitted the prices advisedly. The schedule from which the foregoing items were taken does not coincide with the "Standard Method of Measurement" now recommended for general adoption, but it answered its purpose satisfactorily, and had the "Standard Method" been framed in 1911, when the erection of the New Stationery Office was begun, I doubt, in view of the large quantities of materials involved, whether the concrete required for this building would have been billed in "feet cube" or the steel in "pounds."

A short time ago I saw the bills of quantities for reinforced concrete in connection with a large industrial building, and found that the quantities had been prepared somewhat on the lines of the "Standard Method" from complete drawings, showing reinforcements and other work. Bills of quantities such as these may be admirable so far as they enable contractors to prepare close estimates when tendering, and also in regard to the data they provide for the accurate—though, perhaps, unnecessarily elaborate—admeasurement of variations, but I think they are incomplete if they fail to give the contractors the total quantity of concrete in "cubic yards," and that of steel in "tons." It may be argued that the contractors themselves are able to calculate these totals from the details given, but it is not fair that they should be called upon to do so, and it would be better for all parties if the calculations were made by the quantity surveyor. If such totals were furnished, in addition to the detailed quantities which only should be priced, the contractor whose tender is accepted could at once make arrangements for obtaining his materials. Further, it is held by estimators that these total quantities are essential and important factors in arriving at the detailed prices on which the tender is based. The contractors would also ascertain the quantity of cement from that given for the concrete. On the proportions of 1 + 2 + 4 they would probably calculate at the rate of one sack of cement to one-third of a cubic yard of concrete. Thus, the number of yards multiplied by 3 would give the required number of sacks of cement; dividing this number by 11 (where each sack weighs about 204 lb.) the cement would be shown in tons.

The grand totals to which I have referred would also show the ratio of steel to concrete—generally about 2 cwts. of steel to 1 cubic yard of concrete—from which the average cost of the complete reinforced concrete, at per yard cube, could be ascertained and, on occasion, made use of when measuring for certificates in respect of advances. In this connection the surveyor would allow about 60 ft. super of formwork for every yard cube of the finished concrete.

It may be interesting to note that the proportions of the concrete for the industrial building to which I have alluded were 1 cwt. cement, $2\frac{1}{4}$ cubic ft. of sand, and $4\frac{1}{2}$ cubic ft. of aggregate, as against 1 + 2 + 4, the slightly richer brand adopted by the Office of Works.

Some idea of the magnitude of the New Stationery Office may be gathered from the fact that 10,500 cubic yards of reinforced concrete and about 1,100 tons of steel were needed for its construction. These materials were put together on the Hennebique System throughout.

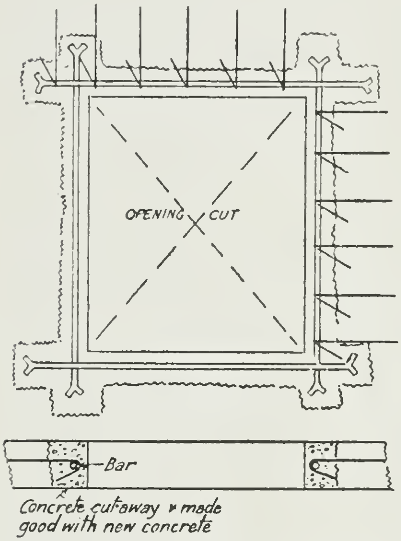
As might be expected in a building of this description, there was a large amount of repetition. Many beams and columns were of the same size, the result being that the contractors were able to use their formwork to great advantage. I believe that only about one-third of the formwork provided in the bill of quantities was actually required on the job.

The contractors also had the advantage of being able to make up on the ground-floor level practically the whole of the reinforcements for the beams. Hoisting into position with the aid of the travelling cranes was a simple matter.

A " Kennedy " bar-bending machine, and another of Chatelier's design, did what was required in shaping the rods.

This building has been converted for the time being into a hospital—known as the " King George Hospital." With this successful adaptation before us there would appear to be no further ground for the objections which have been raised to erecting buildings in reinforced concrete owing to the difficulties and costs that might arise in making alterations in the event of changes taking place in ownership and business.

Fig. 1.



Method of forming an opening in an existing reinforced concrete wall or floor slab. The reinforcement is cut off and bent around the new trimmer bars, as shown.

A few years ago some hesitation existed with reference to cutting into reinforced concrete walls, apart from the question of cost, but we are now getting bolder. In *Fig.* 1 a common method is shown of forming an opening in a wall or floor slab. The ends of the new trimmer-rods might be bent thus : ⌈ ⌈, instead of being fish-tailed.

No doubt it is true that difficulties arise in obtaining satisfactory tenders for the demolition of reinforced concrete structures : a case is recorded in which the cost of demolition amounted to double the cost of erection.

There is no reason, however, why blasting operations should not be put into force in cases of extensive alterations, or where pulling down is required, provided that an experienced hand does the work, and that proper shields are used. A large amount of blasting has been done for the Office of Works in connection with the removal of old foundations and no accident has occurred. In the case of the old cement concrete foundations, 9 ft. or 10 ft. deep, which had to be removed on the other side of Great George Street, gelignite cartridges were employed, and the holes for receiving the charges were formed by an electric drill. The operations were quite successful.

New Science Museum, South Kensington.—I may now submit some notes in connection with the New Science Museum, South Kensington. This important building, which is being erected on a site of about two acres, is of reinforced concrete with a Portland stone front to Exhibition Road, and other fronts faced with brickwork in conjunction with stone strings and cornices. As regards the interior, the whole of the exposed face of the concrete is to be rendered in Portland cement (1 of cement to 3 of sand) finished with $\frac{1}{8}$ in. Keene's cement.

The building is designed on substantial lines; so much so that its appearance when complete will hardly suggest the presence of reinforced concrete.

The most interesting features are the two arched roofs and their continuous lantern lights. These roofs are of 34 ft. and 42 ft. span respectively. Some difficulties are presented by the formwork to the arched ribs, especially as the sides have to be panelled out. The reinforcements here also call for special treatment, but they are assembled before being hoisted into position in the rib boxes.

All the steel rods are being obtained from Earl Dudley's Steel Works, Brierley Hill. Some of the rods for the long beams have been supplied in lengths of 73 ft. No extra charge is made for rolling, but there is one in respect of carriage. These rods are 1 in. in diameter, and, for greater ease in handling and bending, are taking the place of $1\frac{3}{8}$ in. rods, an additional number of rods being put in the beams.

The Coignet System is adopted in this contract, the rods and links being calculated and specified to the $\frac{1}{16}$th of an inch in diameter—quite fine enough for all practical purposes. I know, however, of a building for which some reinforcements were specified to the 1-64th of an inch in diameter. The concatenated mass of rods in this museum makes one wonder how the aggregate (graded from $\frac{3}{4}$ in. mesh downwards) is worked in, but some ingenious appliances are being used, known as " rammers " and " slicers," with which the punning and surrounding is done very satisfactorily. In order that the wire for binding purposes should not be wasted or misapplied it is cut to the required lengths in combined strands, leaving no ends to be dropped into the formwork or concrete.

No overhead machinery for placing materials in position is to be seen. Ordinary scaffolding is employed, but it is put together on the " Scaffixer " system. The lay-out of the plant has been well arranged, the cement stores, ballast, and sand being close to the mixer. The latter—one of Ransome's—is worked by electricity, and mixes about one-third of a yard cube of concrete at one time. As at the New Stationery Office, the concrete is made in the proportions of $1+2+4$. The process adopted is to fill the feeding hopper to the mixer with a gauged measure of ballast, another of sand, and a sack of Portland cement (about 204 lb.). After tilting these materials into the mixer, water is added immediately from an adjustable gauge tank, when the whole is thoroughly churned—usually for about a minute and a half. The resulting mixture is then discharged into a tip-wagon and conveyed on a light railway through the building, or to the sides of the building, where electrically-driven hoists raise it to the required levels. Boarded aprons protect the structure where the hoists operate. The quantity of water supplied to the mixer depends to some extent on the weather and the state of the ballast and sand. In wet weather, when the latter materials are damp, the gauge is adjusted accordingly, but only an experienced man is allowed to decide as to the quantity of water proper to the varying conditions.

The formwork in this building is, in some parts, very intricate, and, except in regard to the floor-slabs, there is little that can be used more than once. It is put together with wire nails (3 in. and 4 in.), which may be clawed out readily as they are not driven right home.

It may seem fitting to state here, after my early reference to railways, that the new museum will probably house George Stephenson's famous engine " The Rocket," and other machinery now to be seen in the adjacent building.

Leaving the New Science Museum, I now turn to a few general notes which are somewhat disjointed.

GENERAL NOTES.

During the erection of a reinforced concrete building care should be taken to prevent the concrete from adhering to any party-wall of adjoining property, otherwise damage might be caused to the latter in the event of a severe frost, owing to the contraction of the reinforced concrete. Sheets of felt placed to separate the new concrete from the old structure have been found most effectual.

Pronouncements are invited on the following points about which there is diversity of opinion among experts:—

Formwork.—While some authorities allow the formwork to be covered with a wash of lime before the concrete is deposited, in order to ensure good surfaces when the centering is struck, others regard it as unnecessary, and are satisfied if the boards are kept well wetted. And while the formwork is treated with " concrete oil " in some cases, it is condemned in others. It is certain, however, that the formwork should not be oiled if the concrete is to be plastered.

Waterproofing.—Differences of opinion also exist as to the best means of making concrete waterproof. Experts agree, however, that the concrete should be moderately rich and that the aggregate and sand should be so well graded as to fill, if possible, all pore spaces. The concrete should be mixed and laid with the greatest care, and should be allowed to set and harden before its permeability is tested. Some authorities state that the mixture should be " fairly wet," and that " on no account should a dry mixture be made if intended to be watertight." On the other hand, one authority states that the mixture should be " fairly dry " and " well rammed in thin layers."

Concrete Roof or Flat.—Coming to the concrete roof or flat, with its covering of asphalt, the question arises whether the concrete should be finished smooth with a rule, or receive, while it is green, a floating of cement. Either course provides the necessary even surface for the asphalt, which should be applied in two coats, the first being more bituminous than the second. When this method is followed very little trouble arises from expansion and contraction, although, in the case of a very wide flat, unbroken by skylights, it would perhaps be advisable to form expansion rolls in the asphalt. One well-known firm of asphalters prefers to lay the asphalt (two thicknesses of $\frac{3}{8}$ in.) on stout canvas nailed to a cement floated surface with zinc nails. It appears that asphalt will adhere very firmly to concrete walls or flats if the surface of the concrete is first painted with coal tar. The latter should be "heated in small quantities, brought just to the boiling point, and then applied immediately."

Systems of Reinforcement.—With regard to the various "systems" of reinforcing concrete, can it be declared whether there is cause or just impediment why the rods in beams should not be slightly larger in section and fewer in number? It certainly seems feasible that they should in no case be nearer to each other than 2 in. in order that it may be tolerably easy for the concrete—not thinned out, but containing its proper proportion of aggregate—to "surround" the reinforcements, and thus have a chance of doing its full work.

Reinforced Concrete Poles and Posts.—I now draw attention to an account given by Mr. Francis B. Shaw in *The Electrical Review*, November, 1914, of "The Government Electric Power Station of Bangkok." Reinforced concrete lattice poles and lamp-posts are described and illustrated. I quote two paragraphs:—

"For the past eight years the Siamese Government have been using reinforced concrete poles of various types both for street and park lighting, and also for transmission lines. Previous to this teak poles and certain other woods more or less unattacked by the white ant were used."

"The wooden pole has usually a pointed or rounded end, and requires elaborate cross-tree timbering to prevent movement or sinkage. Another point not usually taken into account is the elasticity of the reinforced concrete pole. With a teak-wood pole line, if by reason of a tree falling on the line, or a fire, all the lines between two poles are broken, the wooden poles usually give in the ground, and require very careful straightening. With concrete poles this is not the case, as they are sufficiently elastic for the strain to be distributed along several poles on either side without any movement of the pole bases."

This elasticity is one of the most remarkable characteristics of reinforced concrete.

Concrete Rafts.—A reference to a reinforced concrete cathedral may be of interest. *The Builder* of November 13th, 1914, gives some illustrations of a new Roman Catholic cathedral, in Georgetown, Demerara, which is to take the place of the wooden structure destroyed by fire. Quoting from that journal: "The only building material in the neighbourhood is timber, and this is generally used in the colony. The Dutch in olden times, however, made bricks, and some are still imported at great cost; but the ground is so treacherous that it will not carry the weight of a building constructed in the ordinary way of bricks and mortar—*i.e.*, with thick walls such as one is accustomed to in this country. Plenty of gravel and sand, however, can be had, and it has therefore been decided to build a reinforced-concrete cathedral, as light as possible in construction, the weight of which will be carried on a concrete raft covering the whole area of the building, so as to distribute the weight evenly over the entire area. By doing this a maximum load of 10 cwt. per foot will not be exceeded, and the ground will carry this without difficulty."

The value of the concrete raft cannot be over-rated. Without it the important monolithic character of a reinforced concrete building is, to some extent, in danger of being lost; but where it exists the building may assume one of the leaning attitudes peculiar to Swedish drill and yet be manœuvred back safely to the perpendicular. The raft also forms a secure foundation for beam-props, which should always have unyielding bases. A case is known in which the roof to a one-storey building entirely collapsed owing to the props sinking in soft ground.

Further information in respect of Georgetown Cathedral, with some illustrations of the reinforcements, may now be found in *The Builder* of December 17th, 1915. It appears that the raft, 5 ft. in depth, was "designed with a top and bottom slab, 4 in.

or 6in. thick, and divided up into panels about 6 ft. square, with longitudinal and transverse beams. Owing to the importance of getting as even a distribution as possible over the soil, the bottom panels were omitted in certain cases under the lighter portions of the building, so as to increase the unit load on the ground and make it correspond approximately with the unit load occurring under heavier parts." The window tracery will be executed in concrete, and, as stated, "the whole building is full of interest, and forms a good subject for the study of advanced construction, from the theoretical and practical points of view."

An example of the application of reinforced concrete on a gigantic scale is Traymore Hotel, erected recently in Atlantic City, N.J., the largest building of its kind in the world.

It would appear that this enormous hotel, with its bold and complicated construction, expresses the last word in regard to the adaptability of reinforced concrete.

CONCLUSION.

According to the title of a technical journal we are now living in the "Concrete-Cement Age." This is hardly the case, at any rate so far as this country is concerned, but it is very probable that reinforced concrete will be used increasingly for building purposes in the future: its many advantages—economical and hygienic—being already widely known and appreciated. It is possible that this material will develop the "Rectangular" style of architecture, in which the perpendicular lines of piers or counterforts are met by the horizontal lines of sill and string courses—but it seems to be specially adaptable for treatment in Eastern styles, with minarets, cupolas and domes, and with heavy cornices and projecting balconies to give shadows and artistic effect. Architects will have occasion to bear in mind the stereotyped phrases "simple massiveness" and "noble proportions" when dealing with this material. It is to be hoped that they will not be afraid of plain surfaces, as we have no wish to see the external faces of concrete buildings "embellished" with series of bull's-eyes, or set out in sunk or raised panels. Cottages should be designed to harmonise with their surroundings, and might be tinted with pleasing effect, or partly enclosed by trellis-work for supporting the climbing rose or geranium. Factories present a more difficult problem, and they will always look aggressively ugly if erected in rural districts where any structure that is not time-worn appears incongruous. There is no reason however, why they should be of the sky-scraper pattern—the huge perforated box placed on end—and neither is it necessary that the sky-line should be broken by a horrible display of saw-toothed roofs. A little ingenuity, stimulated by some consideration for the owners of adjoining property and the feelings of the passing stranger, should render it possible to build on utilitarian lines without creating monstrosities at sight of which a lover of rural scenes is brought to a standstill with an indescribable sense of pain.

Let us see to it that our reinforced-concrete buildings are as beautiful as art can devise and funds permit. Mistakes have been made in the past: they have taught us much, but there is still much to learn. We must, therefore, press on to a fuller knowledge of this wonderful building material—of the science that governs its construction and the art with which it should be applied. Difficulties will confront us, but they will not be so formidable that they cannot be overcome.

"The distant mountains that uprear
Their solid bastions to the skies,
Are crossed by pathways that appear
As we to higher levels rise."

DISCUSSION.

Sir Henry Tanner, C.B., I.S.O. (Fellow), in proposing a hearty vote of thanks to the lecturer, said Mr. Kearns had invested a most prosaic subject with a certain amount of picturesque language and an extract from the poet Cowper, who certainly never saw reinforced concrete. In mentioning that in a recent earthquake the only building left standing was one of reinforced concrete, Sir Henry said he had had something to do officially with both H.M. New Stationery Office and the New Science Museum. Each of these buildings was began before he had ceased to have direction of the architect's office, and they had got to the section plans, from which point Mr. Allison carried on the work. The new Science Museum had a cubic area of 4,732,000 ft., and H M. Stationery Office of 5,000,000 ft., with average floor space of 280 ft. and 322 ft. respectively. These buildings were peculiarly adapted to reinforced concrete construction, where large spaces were required for storage to a considerable extent, and works were erected for heavy loads on the floors with no great height between them. There was nothing novel in the Stationery Office, but the new Science Museum was a little out of the way with circular ridges. As to the specifications, they were carried out long before the London County Council Regulations came to the stage of being utilised. Both buildings cost 1·85d. and 1·83d. per cu. ft. The gantries at the Stationery Office cost £4,000, and to repay that sum they ought to be used more than once. That was the original intention and idea, but naturally he thought they were too costly. References to the period when coats of plaster should be applied, how quantities should be expressed, the proportion of 2 cwt. of steel to one cubic foot of concrete, to blasting, the size and number of rods, and waterproofing were made, and Sir Henry Tanner concluded by stating that he failed to see why architects could not apply a stone or brick front to a concrete skeleton, while they made no difficulty about it in a steel structure.

Mr. Geo. Corderoy (Member of Council) seconded, and mentioned as a coincidence that the London County Council Regulations were only formally sanctioned by the Local Government Board on January 1st, thus making it at last permissible to erect a building entirely of reinforced concrete within the London area, and he presumed similar regulations would come into force for other civic and county areas. The result could not fail to give an impetus to reinforced concrete construction. They were indebted to the author for giving a lighter atmosphere to the subject. He considered that when cost was an element of consideration in building it was necessary to specify locally obtained materials rather than ideally perfect materials. In his opinion the richer composition of the reinforced concrete for the Stationery Office was necessary. With regard to test cubes, the author did not say whether they were hand rammed in wooden moulds or whether metal rammers into iron boxes were used. The latter would give an experimentally compressive value of 50 per cent. in excess of what would be actually obtained. To his mind there were advantages in the uniform use of one unit of measurement, which was unaffected by the quantities involved, and he cordially endorsed the standard method. The suggestion that the totalisation of the concrete, steelwork and formwork should be ascertained by the surveyor in the preparation of quantities, and made use of when measuring for certificates, was a good one. Greater accuracy still might be obtained by the calculation of this unit price per foot cube for each of the various classes of structures such as piles, floor beams, and so on. There was no true comparison between the old foundations removed in Great George Street and reinforced concrete foundations, where the rods would give a great deal of trouble in blasting. Difficulties might arise from a concatenation of a mass of rods in one situation. The grouting up of rods should be avoided, and it was important that the concrete should be rammed around them, and thoroughly adhere; he believed much more care was now being taken. The Port of London Authority directed that the centreing of the formwork was to be wetted and limewashed, and that before any concreting was done all moulds and centreing should be carefully examined, and the inside of all moulds carefully cleaned out. He did not admit that waterproof concrete could be made, but the finer the aggregate the more watertight was the concrete likely to prove. The modern tendency was towards using smaller rods. He sympathised with the hopes that they might see beautiful and dignified structures designed and erected in reinforced concrete, which would test the powers and genius of architects and engineers. It was, however, only one of many methods of construction, and though the material had special adaptabilities, and would be largely used for many purposes, he did not think it would be so universally adopted for building construction as enthusiasts believed.

Professor Henry Adams (Fellow) considered the paper more readable than the majority of treatises on the subject. Reinforced concrete was sometimes stated to be cold and cheerless, possibly due to the character of the material, which encouraged the deposit of moisture on a sudden rise of temperature. After dealing with the cause of cracks (some of which were due to the shrinkage of the ground) and ventilation of chimneys, the speaker referred in technical detail to the standard method as having been carefully considered, to the London County Council Regulations with regard to rods, the mixture for waterproof concrete, the size of rods, and to the asphalting of concrete roofs.

Mr. J. H. Blizard (Fellow) gave several instances of his experiences with specialists on the subject, and said he was disappointed in the sense that more information was not given as to the practical results from a financial point of view.

The Chairman, in putting the vote, which was carried unanimously, said that the paper and discussion had opened his eyes to the high state of perfection to which reinforced concrete had been carried, and it appeared likely to extend further. As to its usefulness in a small way, Mr. Oakley said he had used it advantageously for agricultural buildings. Another thing which had impressed him was the extraordinary figures given of the cost per foot cube.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

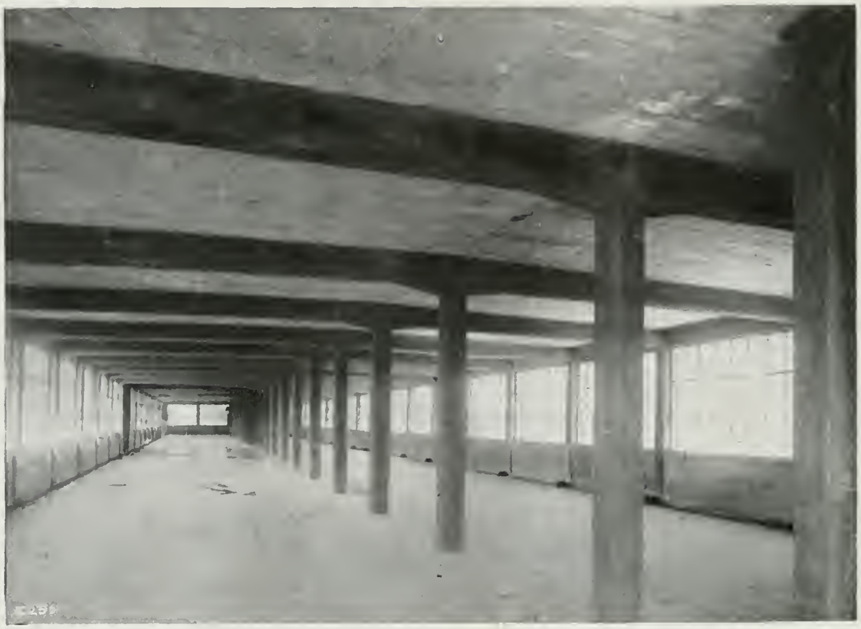
A LARGE REINFORCED CONCRETE PAPER WAREHOUSE.

To replace a large paper warehouse destroyed by fire at Stoneywood Paper Mill, Aberdeenshire, a reinforced concrete building on the Considère system was erected, the construction being steel frames with concrete walls and wooden floors. In clearing away the débris of the fire—an expensive and lengthy process—all the damaged steel had to be cut away by oxy-acetylene jets. The new building, now completed, is of a similar general plan to the old one, but of less height to reduce fire risk.

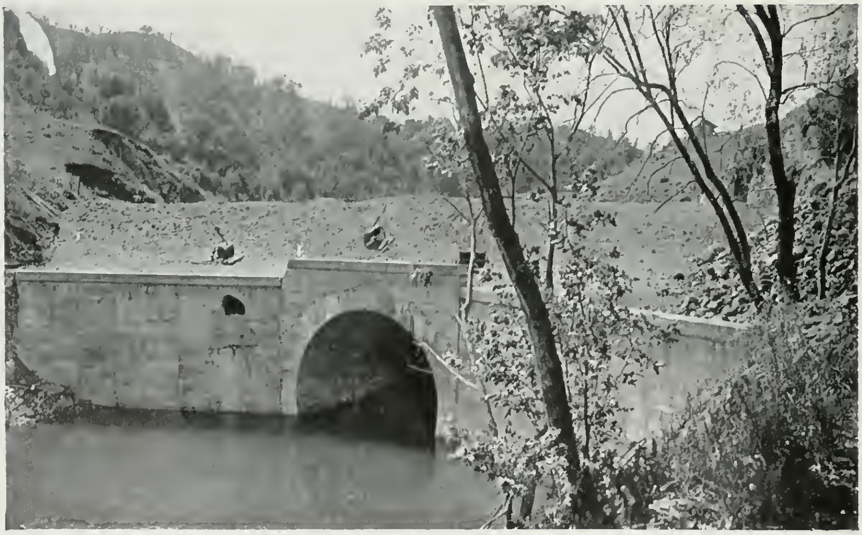
STONEYWOOD PAPER MILLS AFTER THE FIRE.

The building is, in dimensions, 221 ft. by 210 ft., and is two storeys high, with four light wells in the centre.

The ground floor has an area of 5,100 sq. yds., and is used as a store for finished paper, for packing and despatching, and offices. The first floor has an area of



INTERIOR VIEW OF NEW REINFORCED CONCRETE WAREHOUSE.—BAY ON FIRST FLOOR FOR PAPER FINISHING, SHOWING CONTINUOUS WINDOW SYSTEM.



DOWN-STREAM TOE OF CALAVERAS DAM, SHOWING OUTLET PORTAL OF CONCRETE CULVERT.

3,800 sq. yds., and is used exclusively for hand overhauling and finishing. It is served by two 3-ton electric hoists and several staircases. Flat roofs have been designed and these are covered with natural rock asphalte. A feature of this heavy, fire-resisting warehouse is the amount of light obtained in the ground floor, even when the sun is not shining. This is obtained by the planning, and also by the introduction of steel continuous windows. The architect was Mr. H. Maclennan, of Messrs. Jenkins and Marr, M.Inst.C.E., Aberdeen; and the reinforced concrete work was carried out by a local contractor under directions from The Considère Construction Company.

THE CONCRETE STORM WATER CULVERT OF CALAVERAS DAM AND RESERVOIR, SAN FRANCISCO.

In our frontispiece to this issue we show the concrete storm water culvert of the Calaveras Dam and Reservoir in course of construction. The construction of this culvert is of some interest. The culvert is 1,312 ft. long and rests for its entire length on bedrock. In order to keep the bedrock contact and retain grade the invert of the structure is in places 12 ft. thick. The interior section of the culvert is horseshoe shape, the area being 315 sq. ft.

At the entrance of the culvert there is a low circular weir 40 ft. in diameter, which may be raised by flashboards in time of small flow. The concrete used was 1 part Portland cement to 6 parts washed unscreened gravel.

CORRESPONDENCE.

Under this heading we invite correspondence.

AMOUNT OF CEMENT IN VARIOUS 1–2–4 CONCRETES.

To the Editor, CONCRETE AND CONSTRUCTIONAL ENGINEERING.

SIR,—Through the columns of your journal I beg to draw the attention of those engaged on researches in concrete, as well as others equally interested, to a few points that numerous tests which I have made from time to time suggest to me.

First and foremost, I wish to make a strong appeal to those engaged on concrete research not only to give the usual information—such as proportions of mix, sizes of material, age, etc.—but to give also the following very necessary item: *the percentage of cement content in the finished concrete,* or, in the form of a fraction,

$$\frac{\text{Volume of cement used.}}{\text{Volume of finished concrete.}}$$

In order to show the need for this I will state that out of twenty mixes of concrete, using different materials, to the common proportions 1—2—4, and all made for the same purpose and at the same time, there was produced a minimum ratio $\left(\frac{\text{Vol. cement}}{\text{(Fin. volume)}}\right)$ of 1 to 5·6 and a maximum ratio of 1 to 4·33, these being based on the dry volume of cement introduced. If based on the wetted volume of cement, the ratios become 1 to 8·0 and 1 to 6·2.

The next point is that the one with the least cement was weakest, while the one with most was strongest. The weakest was gravel, and the other stone. Now that, to some, condemns gravel; but they are unfair. Give the gravel an equal chance by allowing it as much cementing material for the finished volume of concrete produced as with the stone, and also by reducing the ratio of sand to large material; it will be found, all other things being equal (materials of approximate equal size, equally clean, and same treatment), that practically no difference will exist. Two reasons exist for the suggestion to use less sand:—

(*a*) Gravel contains (usually) a smaller percentage of voids than stone.

(*b*) Gravel is more easily "lubricated" into position by the sand and cement than is stone, because of the rounded particles.

The third point is that on the usual specification for 1—2—4 concretes, the contractor using gravel can produce a structure of a given size with the use of 100 tons of cement, whereas another would use 128½ tons in a stone concrete.

There are two ways of looking at this—(*a*) the contractors', (*b*) the engineers'.

The contractor could save 28½ tons of cement, plus the saving in not having to handle this quantity—a total saving worth effecting. The engineer can be sure that his structure is almost proportionately weaker.

It was on reading a report of tests on (1) gravel, (2) limestone, and (3) slag, as large aggregates all mixed 1—2—4, where the strengths were low for gravel, medium high for limestone, and high for slag, that prompted me to write to you. Should this catch the tester's eye, I beg of him to make up another batch of each, but with *equal percentages of cement* and of *equal working consistency,* and report once more with the old figures alongside.

Yours faithfully,

H. C. JOHNSON,

Engineering School, University College, Cork.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Limes and Cements: An Elementary Treatise. By Ernest A. Dancaster, B.Sc.

London: Crosby Lockwood and Son. 1916.

The attempt to cover the whole subject of limes and cements, including bitumen and mastics, in less than 200 pages is a bold one, and the author has achieved a surprising amount of success. Obviously it is impossible in such a compass to enter at all fully into the various subjects considered, but the task of condensation has been well performed, and the book forms a useful and trustworthy introduction for readers approaching the subject for the first time. The descriptions of plant are clear and adequately illustrated, and this is the case with the accounts of technical processes generally. Chemistry is very briefly treated, but the constitution of cement is reviewed in 14 pages, which actually contain an abstract of the principal theoretical views on this question. It is not correct to say (p. 83) that Alite forms nearly colourless crystals. In thin sections the colour is slight, but by reflected light the grey colour of Alite is very characteristic, and contrasts strongly with the porcelain-like whiteness of the intercrystalline material (? eutectic). There are also a few misprints in this chapter. Another point calling for criticism is the account of nitrification or "saltpetreing." It is satisfactory to find this subject treated, as it is usually neglected by writers of text-books, but there is no doubt as to organic matter being responsible, and it was unnecessary to introduce the second theory quoted, that atmospheric nitrogen was taken up. Were this true a discovery of the utmost interest to agricultural chemists would have been made, but there is no reason to suppose that the theory has any foundation.

An outline of the methods of chemical analysis is given, as well as of the principal mechanical tests. To say (p. 184) that the Le Chatelier test for soundness is almost universally employed is to overlook one of the most burning controversies in the cement world. The statement is true of this country and France, but strong opposition has been offered by the chemists of Germany and other countries, and all attempts to devise an international test of soundness have hitherto failed.

There is a full index, and there are few subjects falling within the scope of the book which do not receive mention. As the author gives many references to the literature, the reader who seeks information is set on the track of works in which details may be found.

Rivington's Notes on Building Construction, Parts I. and II. Edited by W. Noble Twelvetrees.

London: Longmans, Green & Co., 39 Paternoster Row.
Price 7/6 net each.

Contents.—Part I.—Building Regulations—Sites and Foundations—Timbering Excavation, Shoring and Underpinning—Scaffolding—Centres and Moulds—Brickwork—Masonry—Walls, Piers and Retaining Walls—Arches, Vaulting and Domes—Chimneys, Stoves, Ranges and Boilers—Damp and Sound Resisting Construction—Iron and Steel Work—Steel Skeleton Buildings—Reinforced Concrete—Fire-resisting Construction—Carpentry—Partitions.

Part II.—Roofs and Roofing—Timber Roofs—Steel Roofs—Roof Coverings—Structural Plumbing—Joinery—Windows and Glazing—Stairs and Staircases—Plastering—Painting and Decorating, Paperhanging—Drainage and Sewage Disposal—Water Supply, Plumbing and Sanitation—Sanitary Fittings—Heating, Ventilation and Hot Water Supply—Gas and Electric Lighting—Gas Fitting and Electric Light Installation—Electric Bells, Telephones and Lightning Conductors—Fire Equipment.

Rivington's Notes on Building Construction have long been known in the building industry, and many years ago were almost exclusively used by architectural students when pursuing their studies in construction, and thus the very title suggests an old friend to many architects in practice to-day. The old editions were written in a manner which appealed to the student, and as the years passed and it became out-of-date many regrets were expressed by those who knew its value in the old days.

The task of revising the whole of the first two volumes has now been undertaken by Mr. W. Noble Twelvetrees, who has been assisted by several contributors, many of whom are men famous in architecture and engineering. This method of producing technical books is becoming very general, and it has the distinct merit in that each section is written by one who has made a special study of the work described in that section.

The two volumes as now revised are thoroughly up-to-date, and contain information on almost every point to be considered in modern construction.

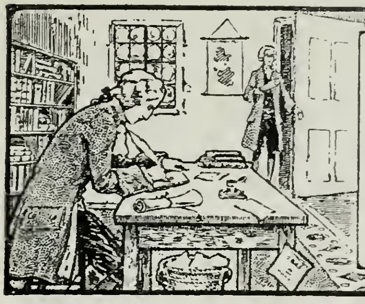
It will be seen that the portion devoted to reinforced concrete occurs in Part I., and it would have been better to introduce this in the second volume, which would naturally constitute the more advanced work for the student. The chapter on this subject possesses little merit, being merely a description of systems employed by various firms which are found in almost every book on the market, together with a few general notes as to the principles governing the use of the material. Considering the importance of a slight knowledge, at least, to every architectural and building student, it would have been worth while giving more extensive notes in the second volume, together with some simple rational formulæ to illustrate the method of designing simple members

The portions devoted to steelwork generally and steel roofs are very good, but here again there has been a tendency to reduce the examples to a minimum, which will be insufficient even for the average student of construction, and when considered as a reference book these remarks apply even more so.

Many of the old illustrations have been retained, and in some instances without adding to the merit of the books, while many of the new illustrations are too small to be suitable.

The volumes certainly vary considerably, and some chapters are excellent, while others are only medium, and it is a pity that the higher standard has not been maintained throughout.

We hope, however, that the books will have a good circulation, as they are well worth obtaining, and although not perfect in some respects they are still quite above the average volume dealing with construction.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Bristol Society of Architects.—At the third sessional meeting of the Society a paper was read by Mr. W. S. Skinner, F.R.I.B.A., on "Modern Cement Manufactories." The various types of machinery used in the manufacture of cement were described and the author traced the materials through the various processes from their raw state to the finished product.

Rifles in Cement—Spanish Discovery.—In a daily paper it is stated that Señor Jose Estrada, the Member of Parliament for Malaga, reported to the Civil Governor of that port that there were 300 large blocks of cement upon the harbour quay there, containing zinc cases filled with Mauser rifles The Military Governor, accompanied Señor Estrada to the quay, and his statements were proved to be correct.

Besides the blocks there are bases and capitals and elaborate columns, all made of cement. Each block contains twelve Mauser rifles, apparently of German make. The blocks, therefore, contain some 3,600 rifles, without counting those inside the bases and capitals.

The Military Governor has placed a guard of twelve carabineers over the whole consignment. Investigations prove that the blocks were shipped at Marseilles, aboard the steamer *Pedro Pi,* having been transhipped from a Dutch steamer. The whole consignment was landed at Malaga over six weeks ago and consigned to order, but nobody has come forward to claim it.

All these blocks are specially prepared to be dropped into the sea at a moment's notice, and each bears initials. In spite of the precautions taken some of the blocks commenced to crack, disclosing a zinc lining, and Señor Estrada was thus enabled to make sure of their contents before reporting the contraband to the Governor.

Table Bay Docks Improvement. — Several solid and useful improvements have recently been made at Table Bay Docks, Capetown, all of which add to the facilities and effectiveness of the port. For instance, there has just been erected a new cargo shed constructed with reinforced Hoy-Rib concrete walls, 2½ in. thick, supported on structural steelwork framing. The shed can accommodate 10,000 tons of cargo. On the road side of the shed the roadways up to the platform are paved with granite setts for accommodation of road wagons to be loaded up. Another instance of the increased facilities at Table Bay harbour is that of the three 4-ton cranes of the compensated rapid luffing type which are being installed at the docks. These cranes were supplied by Ransomes and Rapier, Ltd., the compensated rapid luffing gear, with self-balanced jib, being Mitchell Williams' patent.—*Railway Gazette.*

Concrete Poles for Electric Railways.—A Committee of the American Electric Railway Association has issued a report on "Concrete Poles for Electric Railways." As a result of tests and experience covering a period of several years, the Committee arrive at the following conclusions: (1) Failure of a pole is always due to stretching of the reinforcing rods on the tension side. (2) A failure is always preceded by the appearance of hairline cracks in the concrete on the tension side, at rather frequent and regular intervals from the ground line up. (3) It is advantageous to use a high grade of reinforcing steel to secure the maximum tensile strength. (4) Plain round reinforcing rods are essentially as satisfactory as twisted or other rough rods, because in general the rods will elongate before they slip in the concrete. (5) A larger number of small rods is preferable to a smaller number of large rods, as a better distributed reinforcement may be secured for a given amount of steel and a greater bonding contact surface is presented to the concrete. (6) The reinforcement need not be uniform throughout the length of the pole, but may be stepped off as the top of the pole is approached. (7) A pole with uniform reinforcement will break at the ground line, while one with tapered reinforcement will break at some point above the ground, depending on the taper of the reinforcement. (8) A concrete pole has an element of safety in it, as a failure of the pole will not, in general, allow it to fall to the ground. It is difficult at times to pull over a pole after failure, even though it is inclined at a large angle from the vertical.

Caisson-Sinking and Pier Construction for the New Southwark Bridge Road.—In a recent issue of *Engineering* are given some interesting details and illustrations regarding this work. Steady progress is being made with this bridge.

The work done has been in connection with the founding and building of the piers and lowering of the approaches. There are four piers, the new bridge being of five spans instead of three, in order to coincide with the bridges to the east and west. The piers are all to be carried upon caissons founded in the London clay at a depth of 50 ft. below the Trinity high-water level. Interest is intensified by the fact that two of the four caissons required for the river piers are 102 ft. long by 30 ft. wide, and the other two 100 ft. 3 in. by 29 ft., the weight of each of the larger caissons being 200 tons; these are the longest caissons constructed in this country. The caissons have parallel sides and semicircular ends, and are in all cases 15 ft. high from the cutting edge to the top shelf-plate.

At the present time two of the caissons have been lowered to the bed of the river, while a third caisson is erected and riveted complete upon its staging.* Pier No. 1 (next the Middlesex side) has been built up to half-tide level, and the footings for Pier No. 4 (next the Southwark side) are now in hand. This description applies in the main to the building of Pier No. 1, but the same methods will be used in dealing with the others.

A temporary timber staging was constructed round the site of the new pier, and on this the caisson was built, extra piles being driven to strengthen the staging in the vicinity of the opening for the descent of the caisson, and with additional beams 12 in. square, covered by a decking of planks, to form the platform on which to build and rivet the caisson. To enable the caisson to be completed and caulked it was necessary to raise it from its seat before lowering it to the river-bed. Special lifting and lowering appliances were therefore necessary. They include four timber trestles, four steel girders, four hydraulic jacks, and four steel suspending-bars. Two of the trestles, each formed of a group of six piles driven well into the river-bed and securely braced, were placed on each side of the opening in the staging, and pairs of steel girders spanning the opening rest on these trestles. The hydraulic jacks were supported by the girders, and were connected with the suspending bars or links which hung between the girders and were attached at their lower ends to special lowering brackets secured to certain cross-girders of the caisson at the roof of the working-chamber. Four hydraulic jacks were used—two on each of the pairs of girders. The jacks, with cylinders 130 sq. in. effective area, adapted for a stroke of 18 in., had hollow pistons, through which the suspending-bars for hanging the caisson were passed. These were double bars with slots for cotters at intervals of 18 in. The caisson was lowered by stages equal in depth to the stroke of the jack cylinder.

The caisson was in the first instance lowered about 10 ft. to permit three strakes of temporary caisson to be built upon it. These three strakes were formed of separate panels, bolted together and strutted internally by frames of timber. After these had been fixed, lowering was resumed, with the water at high tide. Immediately on the caisson becoming buoyant and floating, the links were dismantled, and with the jacks and girders were removed for the lowering of another caisson.

The caisson, borne by the water and guided by specially-driven guide-piles at the ends and sides, then descended with the falling tide. At a certain level, in the case of shallow water, it touched bottom. Owing to the falling tide and the loss of buoyancy, it bore heavily on the river-bed, or, as in the case being described, on specially-deposited mounds of hard core, such mounds having been previously deposited on the river-bed at the four points under the points of suspension. The following rising tides again floated the caisson, but meantime it was being filled as rapidly as possible with concrete in the cutting-edge shoe, between the outer shell and the inclined plate forming the sides of the working-chamber, over the roof plates of the chamber and up to the top edge of the permanent caisson. As the operation of filling with concrete proceeded, the additional weight became such that the caisson was not raised off the river-bed, but sat solidly thereon.

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* See *Engineering*, Vol. xcix, p. 565.

The building up of the masonry pier footing courses was then proceeded with. This additional weight, combined with that of the concrete in the caisson, prevented any further vertical movement due to tidal action. The two vertical shafts giving access to the working-chamber, with the air-locks at their upper ends, were then completed and compressed air introduced. As the caisson sank, due to excavation, it became necessary to increase the height of the temporary caisson by adding additional strakes, in order to prevent the inflow of river water into the interior of the temporary caisson, where masons were at work building the lower part of the pier in courses on the roof of the permanent caisson. The additional weight of this masonry also tended to overcome the great increase in buoyancy of the caisson at this stage of the operations, owing to the increased displacement.

The excavation within the working chamber was steadily proceeded with in the clay. On approaching to within about 5 ft. of the foundation level, the clay at each end of the chamber was not removed, but allowed to come in contact with the descending roof of the chamber for a length of about 12 ft. from each end. The weight of the caisson, together with the concrete and masonry, approximated to 5,000 tons, but there was full control of the movements, and the downward travel was easily stopped at the given level. The concrete filling of the working chamber was then placed in position, the clay mounds at the ends being left untouched as long as possible. Grout was run in on the complete concrete under a head of about 3 ft., and after being allowed to settle for 24 hours the air pressure was released, and the removal of the air-locks and shafts proceeded with.

Roof Construction in the New Cathedral, Colombo, Ceylon.—The roofs in this important building are constructed of reinforced concrete, and they have top openings for extracting the heated air. The roofs will be covered with asbestos.

New Grain Elevator for South Chicago.—The John S. Metcalf Co., Ltd., has just been retained by the Chicago and North Western Railway Co. to act as designing and consulting engineers for their new grain elevator plant at South Chicago. This plant will be operated by the Armour Grain Co., and is to be the largest and most complete grain handling and storing house yet designed by elevator engineers.

It comprises a Working House of a million bushels capacity with facilities for receiving grain at the rate of 360 cars in ten hours, and shipping to cars at the same rate. At the same time it will be arranged to dry 90,000 bushels of grain and bleach 240,000 bushels of oats in ten hours, besides enormous clipping and cleaning capacities.

There will be a Marine Tower for receiving from vessels at the rate of 20,000 bushels per hour, and a River House equipped to ship to boats at the rate of 120,000 bushels of grain per hour, and with a shipping gallery to carry grain out along the wharf for trimming the vessels after they have received the bulk of their load at the River House.

Between the Working House and the River House there will be a storage house which will bring the ultimate storage capacity of the plant to approximately 10,000,000 bushels.

All the machinery will be electrically driven, deriving power from a complete independent power plant of 4,700 h.p. Water-tube boilers and turbo-generators will be used.

Complete facilities will be provided for collecting the dust caused by the handling and cleaning of the grain and for sacking this dust or loading in bulk.

An independent office building for convenience of the operators, a welfare building for employés, a shop building, and 1,200 ft. of wharf are also included in the work.

Plans will be submitted to contractors at an early date.

The John S. Metcalf Co., Ltd., has for many years been prominent in the designing and construction of the enormous grain handling plants in Canada and the United States. The headquarters of the company is in Montreal, Canada, with branches in London and Chicago.

Among the many well-known plants designed and erected by them recently, those for the Grand Trunk Railway and the Canadian Pacific Railway on the Georgian Bay, and that for the Port of Montreal, are perhaps the most interesting—especially that for the Harbour of Montreal, the grain-handling plant of which is universally admitted to be the most up-to-date in existence, and has transformed Montreal from a position of negligible importance as a grain exporting centre to the premier position on the continent in this respect. This plant was the subject of an interesting paper read before the Institute of Civil Engineers on April 7th, 1914, by Mr. F. W. Cowie, B.Sc., M.I.C.E.

This firm also designed and constructed the first Manchester Ship Canal Elevator, and the No. 2 Elevator just completed at No. 9 Dock was also designed by them and erected under their supervision. We understand that they are engaged at the present time upon the designs for the silos and grain-handling plant for Messrs. Guinness's new brewery at Trafford Park, Manchester, which will be the most extensive of its kind yet erected in this country.

Effect of Electrolysis on Engineering Structures.—We take the following from a paper read at the International Engineering Congress at San Francisco by Mr. A. E. Ganz:—"Stray current is most likely to reach steel building structures by means of pipes or cable sheaths entering the structure from underground piping or cable systems. It is, therefore, desirable, where appreciable stray currents are found, to instal insulating joints in such pipes and cable sheaths. Where the tracks over steel bridges are positive in potential they should be insulated from the bridge structure, in order to protect the bridge foundations against possible damage by electrolysis.

"To cause damage to a reinforced concrete structure by electrolysis, an electric current must flow between the reinforcing steel and the surrounding concrete. The conditions required for producing electrolysis of steel embedded in concrete are such, however, that this can result, in the case of reinforced concrete structures, only in special situations, for example, where there is an excessive voltage drop through the earth at the foundations of the building, or where stray current is brought by way of surface pipes or cable sheaths into the building and to the reinforcing steel, or where there is a direct contact between the reinforcing steel and one side of a direct-current lighting system, the other side of the system being grounded. It is, therefore, a wise precaution to instal insulating joints in all pipes and lead sheaths of cables which enter a reinforced concrete structure. It has been proposed to protect reinforced concrete structures by making the reinforced steel electrically continuous throughout, and connecting it to the negative terminal of the source of stray current or of a low-voltage generator. While this would prevent corrosion of the steel by electrolysis, it may result in destruction of the bond between the reinforcing steel and the concrete, which results when current flows from concrete to steel.

"In the Grand Central terminal of the New York Central Railroad in New York City the tracks are insulated as far as possible from the structural steel by being carried on wooden ties embedded in concrete or stone ballast, and the latter is well drained so as to be maintained dry. Pipes and sheathed cables entering the structure are provided with insulating joints. Foreign pipes crossing the terminal at street level are carried on wooden supports embedded in sand, which is maintained dry by draining. Also the voltage drop in the tracks is kept very low by having a sub-station located directly in the terminal, and the structure is electrically drained to the sub-station negative 'bus bars. A careful watch is kept of the entire situation in this terminal."

Concrete Culvert Pipes.—The Wannon Shire Council, Victoria, found it necessary to use a heavier cement pipe than those in ordinary use for culverts, and of a shape more suited for the carrying away of dead leaves, branches, and other débris which usually foregather at the mouth of culverts. The design is a most useful one, besides being strong and effective. The pipes were manufactured by unskilled labour under the superintendence of Mr. C. H. Ross Heale, shire engineer. As other councils may find it cheaper to make their own pipes for culverts, the method of manufacture is given below.

The moulds consist of two parts, the inside core and the outer shell, the concrete being poured between the two. The inner core is made so that it can be easily taken to pieces and put together again in a short time.

The bottom tray is made large enough to cover the whole of the pipe section, and is bored to receive the reinforcement. Brackets have been introduced at the bottom to help the uprights to resist the cement pressure; experience has proved that if it be heavily rammed it becomes surprisingly strong. The uprights have pins at each end—one to fit in the bottom tray and the other to fit in the top tray. There are uprights at each corner and one in the centre on two sides; on the other side are two uprights into which the galvanised iron is wedged.

There is also a centre tray. This has a hole in it, so that a hand can be easily inserted to take it out. This tray rests on brackets which are on the uprights and which help to resist the pressure at the centre. This comprises the skeleton of the core, around which is wrapped a sheet of 24-gauge galvanised iron. This iron is held in place by the ends being bent to slip into the two uprights and by a wooden wedge. This holds the iron secure in its place.

The reinforcement is then slipped over, the ends of the upright bars being put in the slots of the bottom tray. It is made of ordinary No. 8 black fencing wire; the long lengths are cut out and straightened, and are bent to the proper design on a wood template, and jointed with a hook joint, the two different reinforcements being tied together with No. 16 gauge wire. There are nine long bars and six circular hoops. They are spaced about 6 in. apart, so as to give 6-in. grids, the long bars being spaced alternately on the outside and inside of the hoops. The whole reinforcement is now complete. A man in one day of eight hours, at 1s. per hour, can quite easily cut and make three such reinforcements.

Over the whole is placed the outer shell. This shell is made of 24-gauge galvanised iron, braced and bolted. Three small pieces of wood are bolted to the mould at the top. This enables the inner core to be kept the same distance from the outer shell, namely, 2½ in., so that the pipe, when made, is uniform. This shell, as shown, is made in two pieces, having plates and small bolts to hold it when in use. The pipes are made with the mould standing upright.

The concrete consists of four parts of bluestone screenings, which are provided by the council's crusher, three parts sand, and one and a quarter parts cement. When the mould is filled the ends of the projecting wires are cut off and stuck into the concrete as an additional reinforcement; the date is then moulded into the end. The cement is allowed to stand for two days, when the outer shell is taken off; it is then allowed to stand another day, when the inner core is taken out. The pipe is kept in a damp state for about a week. It is then placed on a bed of sand, where it lies for a month before being used. The galvanised iron of the moulds is painted with soft soap to prevent the cement from sticking.

The cost of making a mould, including all materials and labour, is about £3 15s. The pipes vary from 16 in. to 18 in. in diameter, are 3 ft. long and 2½ in. thick. The cost of the manufacturing of one pipe is as follows:—Reinforcement (about 20 yards No. 8 gauge black wire, at 16s.), 6s.; labour in making, 2s. 8d.; concrete (one cask of cement, at 25s., will make 5 pipes), 5s.; screenings, nil; sand, nil; labour in mixing, 2s. 8d.; total, 10s. 10d.

Pipes thus made have been used for abutments to footbridges, across creeks, and during the past winter successfully withstood a flood of 6 ft. over their tops. Culverts having only 9 in. of soft earth cover have not been damaged by 12 to 15 ton traction engine traffic. Several pipes have been dropped 5 ft. from lifting slings and have only been chipped on the edges and have not broken.—*Commonwealth Engineer.*

Solid Deck Trestles and Bridges on the Illinois Central. — The Illinois Central Railroad recently opened for traffic about 34 miles of second track between Gibbs, Tenn., and Kerrville, on the main line just north of Memphis, the last single-track mileage between Chicago and Memphis. The construction of this second track involved the handling of 1,300,000 cubic yards of grading and the building of about 9,500 ft. of concrete trestle in addition to other minor bridge work. In the design of these trestles the solid piers which have been used in a number of instances on this road to support concrete slab decks were replaced by concrete pile bents recently

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adopted as the road's standard, the cost of the latter being about 80 per cent. of that of the former. In order to secure the advantages of a solid deck on two 80-ft. through-plate girder structures located between sections of the concrete trestle these bridges were built with concrete slab floors involving a number of interesting details.

The concrete trestle was used in heights ranging from 8 ft. to 20 ft. for practically all locations where timber trestles had been used in the old single-track line. In cases where the old structure in the first track had not reached the end of its life the new concrete trestle was built alongside with the intention of renewing the wooden structure by a second single-track concrete trestle when necessary. In other locations the old timber construction was replaced by a new double-track concrete trestle.

The standard panel length is 16 ft., although in some instances this was varied in order to miss the bents in the old trestle. The bents are of three types, the end, the intermediate and anchor. The anchor piers are located at every sixth bent in trestles of 10 or more panels, serving to stiffen the structure. In the single-track structure the end bents consist of six piles with a cap 20 ft. long, 2 ft. 6 in. wide, and 3 ft 6 in. deep, and a back wall extending 8 in. up on the slab at the ends and to the top of the slab at the sides. The intermediate bents have five piles and the caps are 14 ft. long, 2 ft. 3 in. wide, and 3 ft. 6 in. deep. The anchor bents have a double row of four piles, each with a cap 14 ft. long, 4 ft. 3 in. wide, and 4 ft. 6 in. deep, having a centre wall 1 ft. thick extending up to the top of the slabs. An open space of 2 in. is allowed between the ends of the slabs and the back walls on the end bents and the centre walls on the anchor bents. The heads of the piles are embedded in the concrete cap 2 ft. in the end bents, 10 in. in the intermediate bents, and 1 ft. 10 in. in the anchor bents. When built as a double-track structure the end piers are 34 ft. long and the intermediate and anchor piers 28 ft. long, the two tracks being spaced 14 ft. centre to centre.

The piles used in this trestle are hexagonal, with the lower end pointed. They are reinforced with spiral and longitudinal rods securely tied. The piles were made by the C. F. Massey Company, at Memphis, were seasoned 30 days and were driven with a steam hammer, using a wooden driving block and a rope cushion. The soil was clay and the piles sustained little damage in driving. The reinforced concrete caps were built in place over the heads of the piles. The slabs are of a type used quite generally by this and other companies, the width of each slab being half the width of a single-track structure.

The two single-span through-plate girder bridges with concrete slab floors are of standard design except for the lowering of the stringers and the addition of one I-beam stringer at the centre of the floor beams. The two slabs, which are placed side by side in each panel between floor beams, are supported on nine stringers, the tops of which are 1 ft. 4½ in. below the tops of the floor beams. Each slab is 9 ft 8¾ in. long, the spacing between floor beams, and 12 ft. 9 in. wide. The slabs are cast with a curb along both edges to retain the ballast and across the end to fill the space under the flanges of the floor beams. The upper surface of the slab is pitched 1 in. from each side to the centre, where a 4-in. drain tile is inserted, being covered by a cast-iron grating. The thickness of the slab at the centre is 7½ in. and the maximum thickness over the curb is 1 ft. 4½ in.

The minimum depth of ballast under the tie is 6 in., bringing the bottom of the ties 2½ in. below the tops of the floor beams. The two ties adjacent to each floor beam are held tightly against the flanges by ¾-in. rods 3 ft. long threaded on both ends, which are passed through the ties just outside of each rail and tightened by a nut on each end. The tops of the floor beams are covered by ¼-in. lead sheets, and the curb walls around the slabs, the tops of stringers, and the tops and sides of the floor beams which come in contact with either lead, concrete or timber, and the top surface of the slabs, are thoroughly coated with pitch. A ½-in. space between the slabs is filled with pitch. The slabs for each of these 80-ft. double-track girder spans required 62 cubic yards of concrete.

The whole of the bridge work on this double-tracking project was carried out by company forces under the supervision of the engineering department: Mr. A. S. Baldwin, Chief Engineer; Mr. F. L. Thompson, Assistant Chief Engineer, and Mr. Maro Johnson, Engineer of Bridges and Buildings.

PUBLICATIONS RECEIVED.

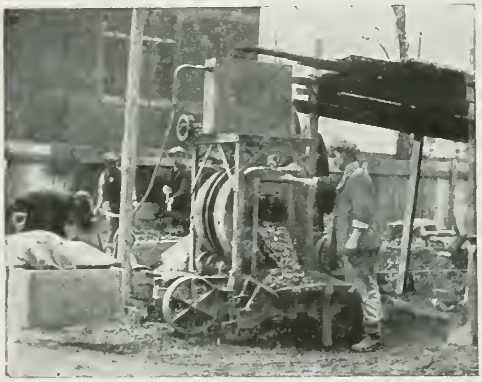
Reinforced Concrete Regulations. — The London County Council Reinforced Concrete Regulations can now be obtained from Messrs. P. S. King and Sons, 2 and 4, Great Smith Street, S.W. The price is 2d., or post free 3d., or with a full index post free 7d.

Memorandum on Chains and Other Appliances, by G. S. Taylor, H.M. Inspector of Factories, obtainable through any bookseller, price 6d. A memorandum dealing with the causes of, and possible means of preventing accidents arising from the fracture or failure of chains and such metal appliances as rings, hooks, shackles, swivels, etc., used for lifting purposes.

Skelton's Handbook on Steel and Steel Construction.—This is a useful handbook dealing very fully with structural steel. The book is divided into two parts. The first part contains all the lists of sections and materials, together with various drawings and tables relating to same. Part 2 consists of notes and data on the design of structural steelwork, and there are also some general data such as tables of weights and measures, etc.

The book should prove useful to engineers. It is compiled and published by Messrs. R. A. Skelton and Co., Moorgate Station Chambers, E.C.

Institute of Arbitrators.—It will be recollected that some time ago we made mention in these pages of the formation of the Institute of Arbitrators. We have now received a copy of their first *Quarterly Journal*, wherein will be found set out in detail the aims and objects of the Institute, to which we have already briefly referred. The Journal also contains a number of short articles on arbitration which will, doubtless, be of interest to many of our readers. The offices of the Institute are at 32, Old Jewry, E.C.



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CONCRETE
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CONSTRUCTIONAL ENGINEERING

Volume XI. No. 3. LONDON, MARCH, 1916.

EDITORIAL NOTES.

CONCRETE THE MONEY-SAVER.

THE urgent necessity for economy in every walk of life is obvious, and while economy may necessitate a delay in the completion of many great public buildings and works, it should be borne in mind that the requirements of the War involve the erection of innumerable buildings, as, for example, factories, warehouses, tenements and cottages, and in all these cases economy is a question of using the right materials.

The Board of Trade has recently issued a list of imports that are to be reduced for reasons of policy and of economy, and that list includes, we are pleased to see, building materials that are not absolute essentials. What we would have liked the Board of Trade to do, in connection with this exclusion of certain building materials, would have been, also, to point out plainly the advantages of many of our home products, not least among them being Portland cement, for every possible form of building construction.

Cement is used in concrete, be it massive concrete or reinforced concrete or the concrete block; it is also used for the finishing of surfaces or in the preparation of the etceteras such as linings, curbs, posts, sinks, etc., and is one of the most valuable assets the country possesses.

We have all the raw materials for making cement and concrete, and we have them close at hand on the majority of sites used for building purposes.

Again, the War makes it necessary to enclose all manner of areas, from the rifle range, the prisoners' camp, the magazine or the small huts that house our Anti-Aircraft forces. Why imported timber should be constantly used for all these enclosures is one of those extraordinary features of economic mismanagement that seems to prevail in some of our Government Departments. Surely nothing would be more useful than the ordinary concrete fencepost, the concrete gatepost, and any other form of post for supporting the barbed wire or other forms of enclosure.

Dealing with the much wider subject of hutment camps and all forms of hutted buildings, whilst we agree that in the early days of the War the very rapid erection of timber structures may have been necessary, we are now at a period where a few days or weeks are of less importance in the erection of these hutments. For such buildings the concrete block or slab would be more economical, as it requires the least maintenance, and above all it provides greater comfort for the user. It is verily appalling to observe the vast amount of unnecessary imported timber used in these hutments, and the time has arrived when these misuses should cease.

What applies to the military hutment camps applies equally to the innumerable accessory buildings of the Salvation Army, the Y.M.C.A., the store buildings and the like, in respect of all of which concrete would be so applicable, and, given a competent overseer or clerk of works, these buildings could then be erected by unskilled labour.

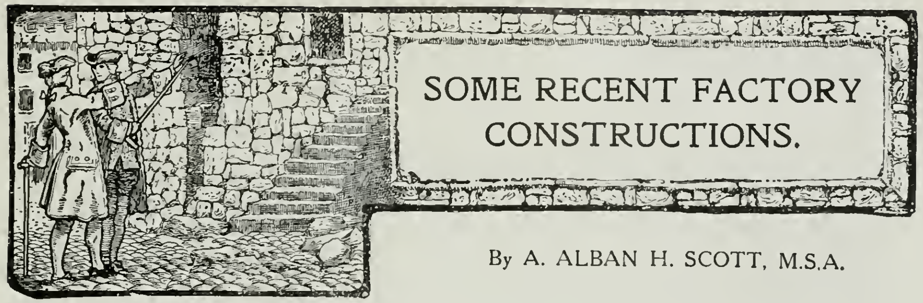
In munition factories the walls and partitions, in workmen's cottages walls and floors and partitions, all lend themselves to the use of concrete. All this does not seem to have been properly realised, with the result that vast sums are being sent abroad for timber.

As far as the ordinary citizen is concerned, we realise, of course, that he is reducing his building operations and his repairs to a minimum; but we would remind the citizen and those who attend to the minor public works that there is no material as useful as cement and concrete.

REINFORCED CONCRETE FOR FACTORY CONSTRUCTION.

We have often drawn the attention of our readers and those engaged in the designing and erection of factory buildings to the economy that can be effected by the use of reinforced concrete for buildings of this type. But in addition to the financial economy that results, there are other equally important factors, chief among them being the additional space gained, and—what is of paramount importance in all factories and workshops—the extra light obtainable.

In another part of this issue we publish an article by Mr. Alban H. Scott, M.S.A., in which will be found some typical illustrations of some recent factory constructions.



SOME RECENT FACTORY CONSTRUCTIONS.

By A. ALBAN H. SCOTT, M.S.A.

The following notes and illustrations give some excellent examples of the application of Reinforced Concrete to Factory Construction.

In factory construction fresh problems arise with each particular building, and it is astonishing when one devotes himself to solving the problem of reinforced concrete how adaptable this material is to almost all the circumstances that arise in constructional works of this description.

In the various numbers of "Concrete and Constructional Engineering" the application of concrete work to the various requirements shows this to a very great advantage, and concrete for industrial premises is now becoming quite the recognised material for this class of work. At the same time there are occasions when concrete in conjunction with other materials forms an extremely useful combination.

One of the many points requiring further investigation and research regarding reinforced concrete is its behaviour under sudden shock and also as to the effect of vibration over varying periods. If the *actual* stresses in the various members, when the structure is fully loaded, could be further investigated not only would the buildings be more economically designed, but such investigation would, it is considered, show that the present method of design could be materially modified.

Although it may only take place gradually, it is felt, for factory construction, eventually the design will become in reinforced concrete more on the lattice principle. Stanchions, for instance, could be standardised for varying loads and heights to carry definite loads, saving considerably in centring and time.

Reinforced concrete purlins for roofs where the span is considerable can also at the present moment be economically used.

Fig. 1 shows the factory and offices with warehouses, recently completed for the "Vi-Spring Works," where the main structural columns are formed of reinforced concrete, together with the roofs and ceilings of the offices and part of the warehouse; but in the room requiring a very large area without the intervention of columns a steel roof has been introduced which gives an exceedingly light and interesting appearance. The large roof illustrated is 160 ft. by 80 ft., with one central column of reinforced concrete only. The steelwork of this roof has been designed on the principle of the Warren roof truss, and the North-light principle introduced so as to give an even light throughout the premises.

From *Fig.* 1 it will be seen that this factory is arranged on the principle that the offices range along one side of the main workroom, raised 2 ft. 6 in. above the general level with a gallery, so that the main room has general supervision from the office portion, and on the right-hand side is the foreman's room, so that he also has good supervision.

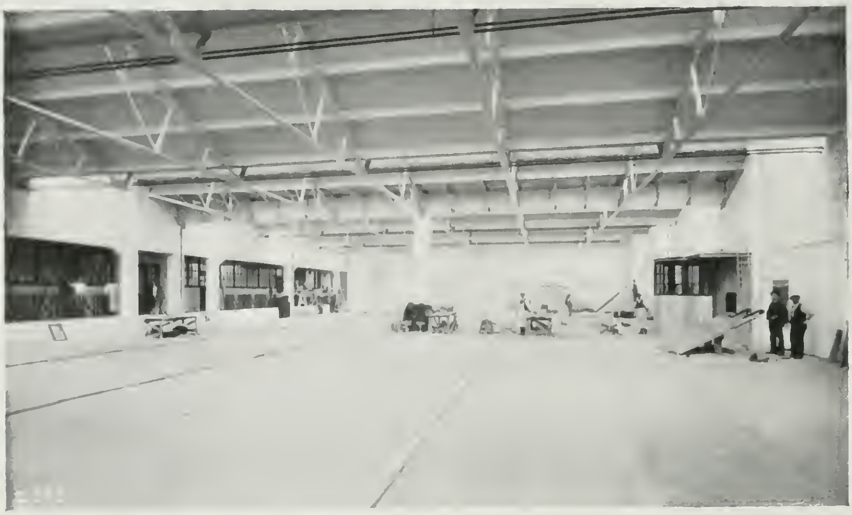


Fig. 1. Vi-Spring Works.

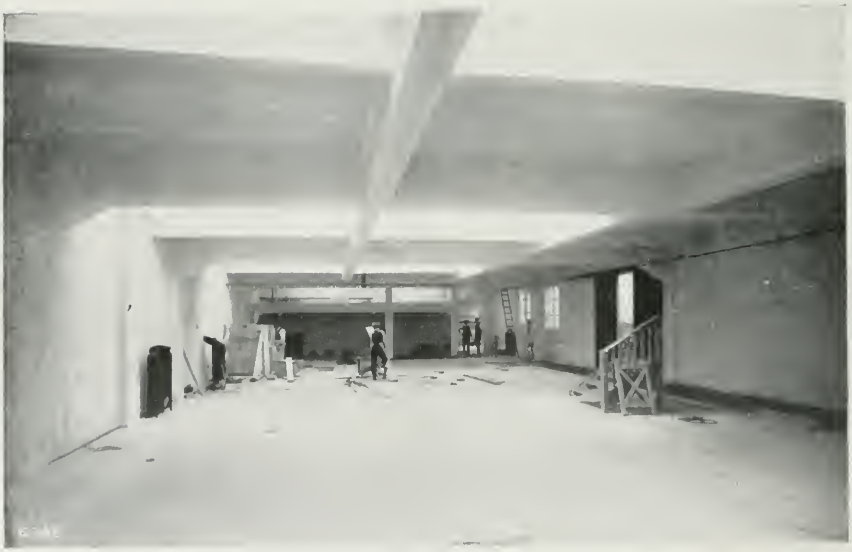


Fig. 2. Room with Reinforced Concrete Roof and Roof Lights.
SOME RECENT FACTORY CONSTRUCTIONS.

In these buildings all woodwork to roofs, etc., has been painted, thus saving the cost of limewhiting every fourteen months.

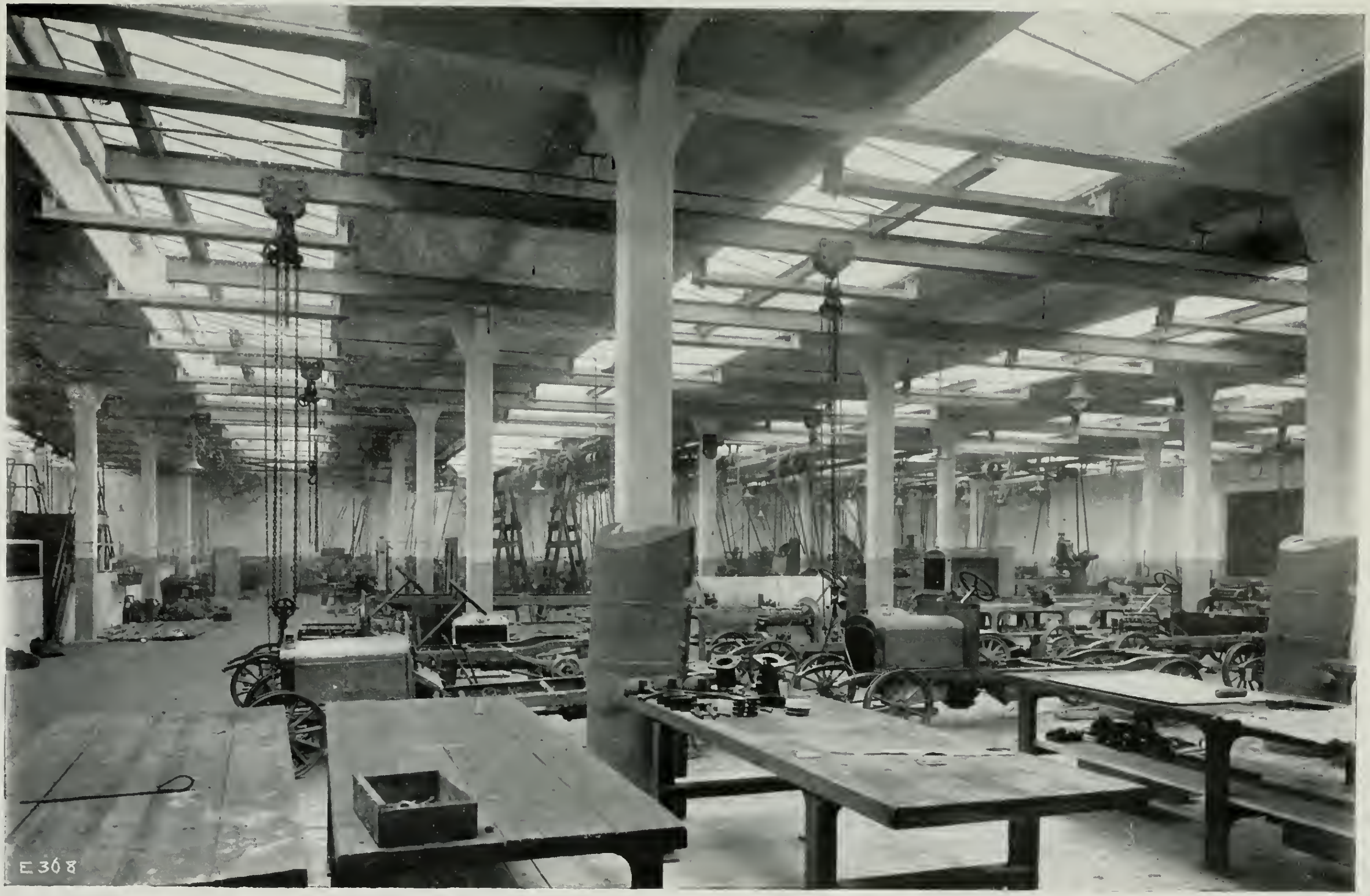


Fig. 3. Showing the Adaptation of Concrete Roofs for Shafting and Runways in any positions.
Some Recent Factory Constructions.

Fig. 2 shows an interesting room with reinforced concrete roof and roof lights introduced in the form of "semi-North lights," being on the same principle as shown in *Fig.* 3, which also indicates how reinforced concrete roofs can be adapted for shafting and runways in any position. In this roof the bolts have been placed in the permanent work, enabling the shafting and runway joists to be placed in any position suitable to the work. This has many advantages, particularly if it is decided to alter the run of the machinery or alter the purpose for which the shop was originally built.

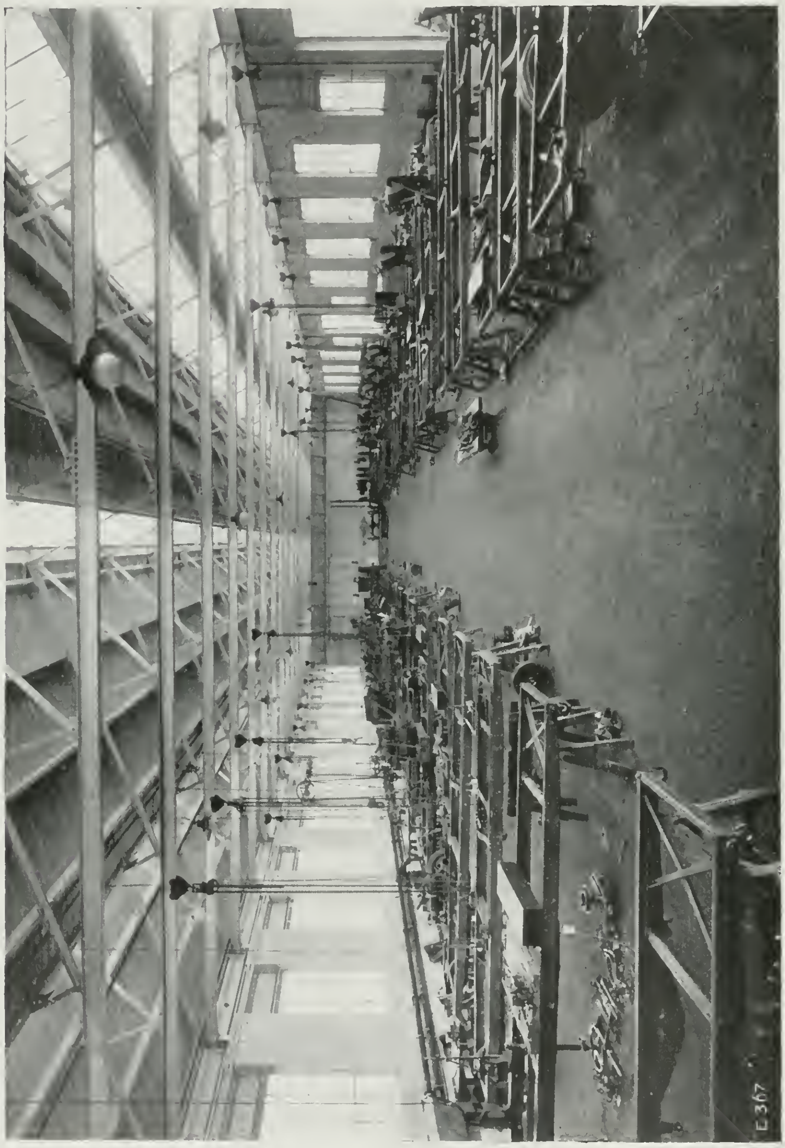


Fig. 4. Showing Special Roof Construction.

Some Recent Factory Constructions.

Fig. 4 shows a similar roof to that in *Fig.* 1, being 70 ft. span, and adapted for runways to lift a fairly heavy weight. This form of factory can be extended in length to an unlimited extent, and could also be increased in width, which has proved a very satisfactory form of building for various purposes, being free from internal columns and easily adaptable to any form of manufacture.

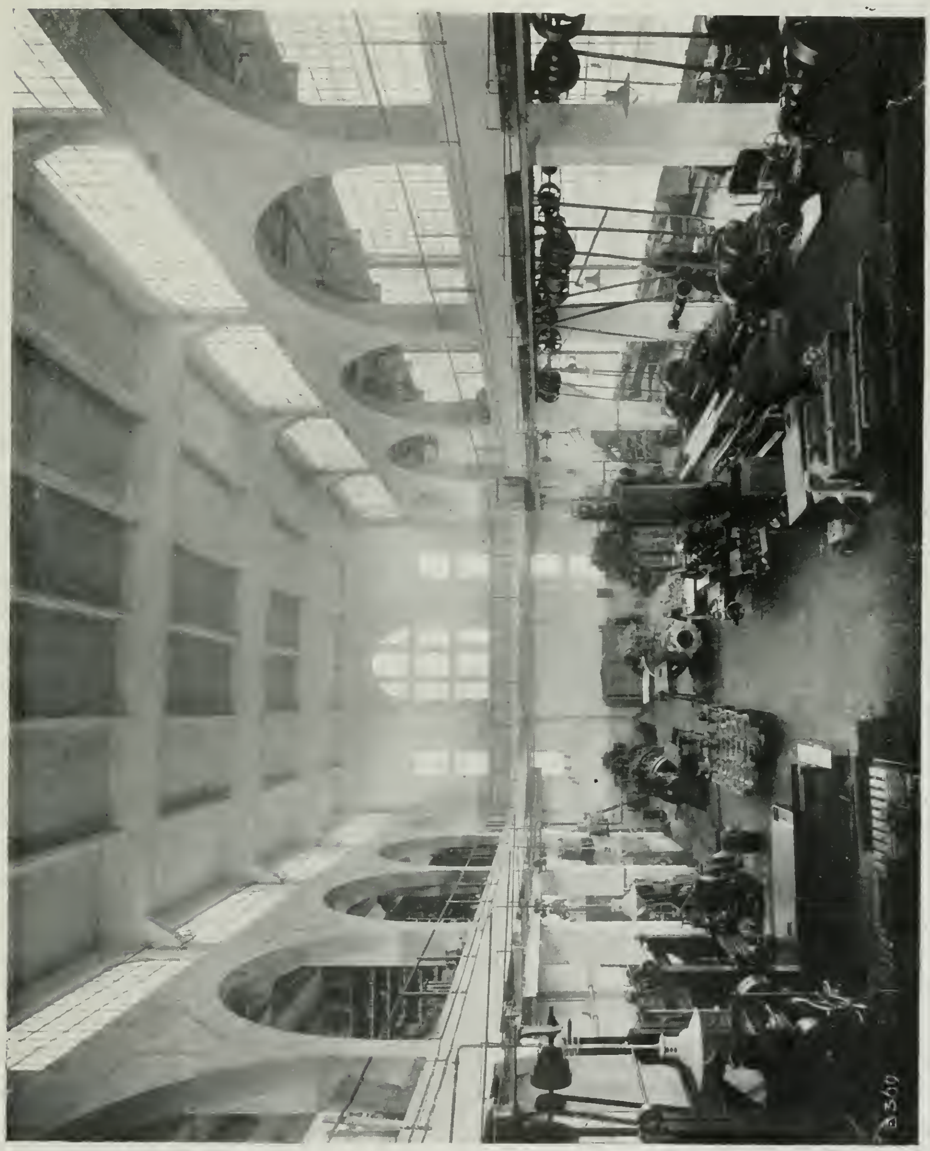


Fig. 5. A Factory entirely of Reinforced Concrete.
Some Recent Factory Constructions.

Figs. 5 and 6 indicate a factory entirely of reinforced concrete, including heavy crane girders, the main shop being 40 ft. wide in one span with flat roof above. The circular arches under the crane rails not only add to the general stability of the building, but give the shop a pleasing and interesting appearance, which one is not always able to obtain with the ordinary straight girders.

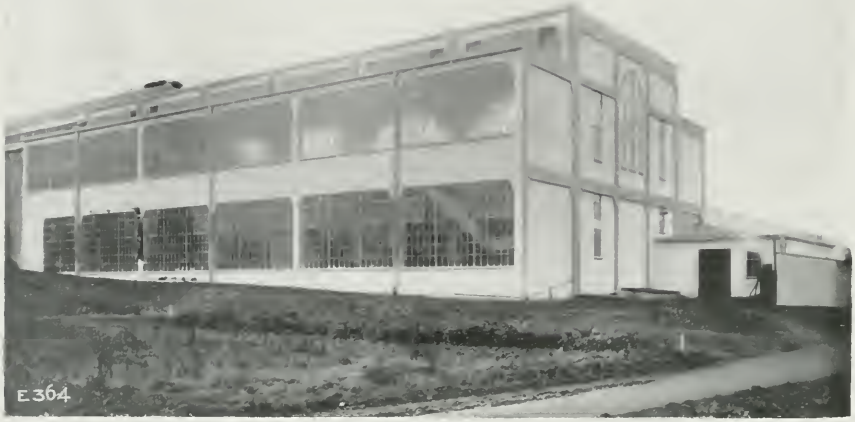


Fig. 6. Exterior of Reinforced Concrete Factory shown in Fig. 5.

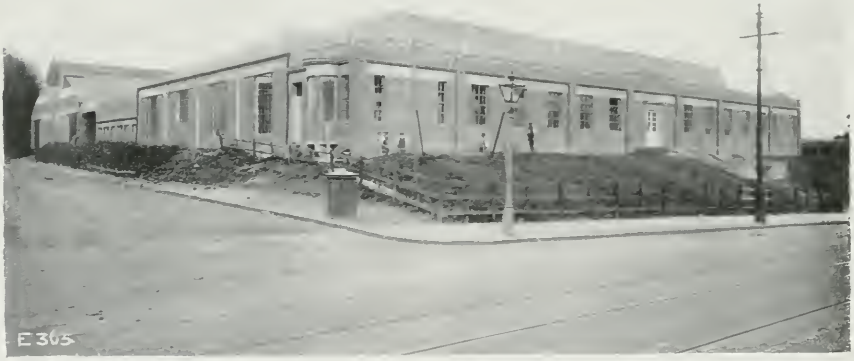


Fig. 7. Shows the Introduction of Brickwork in connection with Reinforced Concrete Beams.
Some Recent Factory Constructions.

Fig. 6 shows the exterior of the same building, indicating the extent to which reinforced concrete can allow enormous lighting areas where light is of great importance.

Fig. 7 illustrates how brickwork can be introduced to harmonise with the reinforced concrete beams, and bands around the building, tying the whole together, and the introduction of the steel sashes to the office portion of the building, making the whole a practically fire-resisting structure.

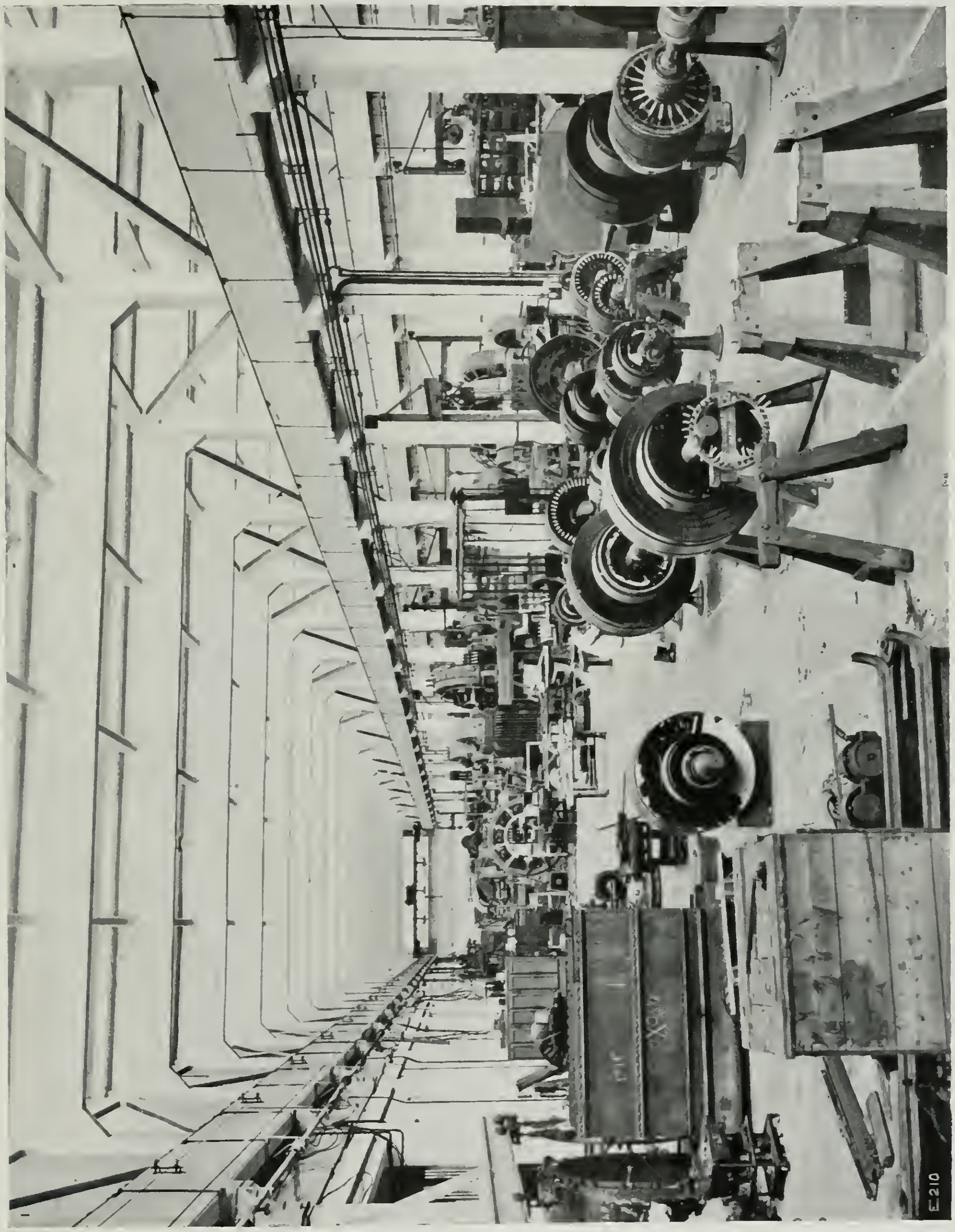


Fig. 8. An Engineering Shop.
Some Recent Factory Constructions.

Fig. 8 shows an engineering shop 600 ft. long in two bays of 50 ft. each, carrying heavy travelling cranes, the whole work, with the exception of glass to roof and doors, being formed of reinforced concrete.

PROBLEMS IN THE THEORY OF CONSTRUCTION.

TORSION STRESSES IN BEAM SECTIONS.

By EWART S. ANDREWS, B.Sc.Eng., M.C.I.

The following article on Beam Sections should be read in continuation of an article which appeared in our previous issue.—ED.

In our last article we dealt with the determination of the bending and twisting moments in beams curved in plan and referred to the recent work by Professor Gibson and Mr. E. G. Ritchie.* We come now to the general problem of the torsional properties of beam sections as used in practice, and of the particular application of these properties to the case of beams which are curved in plan. Both of these questions have been investigated experimentally by Messrs. Gibson and Ritchie. In the present article we propose to explain the principal results of these experiments and to show their application to the calculation of the maximum stress upon a girder as constructed in practice for carrying a bay window.

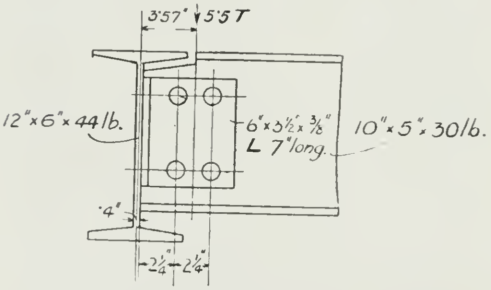


FIG. 1.

We will first remind our readers that the ordinary torsion formulæ, according to which the stress varies as the distance from the centre of the section, apply only to solid and hollow circular sections; they involve the assumption that sections plane before twisting remain plane after twisting, and this is known to be untrue except for the sections named. The subject was investigated fully by St. Venant and his approximate formulæ for sections possessing no re-entrant angles are quoted in the leading text-books on the subject; for the typical sections employed in practice very little information is available as to their torsional strength.

We will deal first with the case in which the twisting moment T is known from first principles, and does not depend upon the deflected form of the structure as it does in the case of the beam curved in plan.

I BEAMS.—The maximum stress caused by torsion of an *I* section occurs at the centre of the web, and is zero at the extremities of the flanges.

As the result of experiments upon *I* sections of lead, Professor Bach found that rupture always occurs at the centre of the web, and gave the formula :—

---

* "The Circular-arc Bow-girder" (Constable). Price 10/6 net.

$$\text{Maximum torsion stress (pounds per sq. in.)} = \frac{4\cdot 5\,T}{A\,t} \qquad (1)$$

Where T = Torsion moment (inch lbs.).
A = Total area of section (sq. in.).
t = Thickness of web (inches).

He gives a similar formula for cast-iron sections.*

Messrs. Gibson and Ritchie have made experiments upon the torsional deflections of I sections, and find that the effective polar moment of inertia of the section is given approximately by the formula :

$$I_{p'} = \frac{A^2}{60} \qquad (2)$$

This, however, does not give the *strength* of the section ; to estimate this they consider the strength of the web alone, by Auteureith's formula for a solid rectangular section, according to which the maximum stress occurs at the neutral axis, and is given by the formula :

Maximum torsion stress (pounds per sq. in.) =

$$\frac{5\cdot 14\,T}{d\,t^2} \qquad (3)$$

Where d = depth of section (inches).
t = thickness of section (inches).

This leads in the case of the 8 in. by 5 in. beam which they tested to a formula in close agreement with Bach's formula (1), and in the absence of further information upon the subject this formula may be adopted.

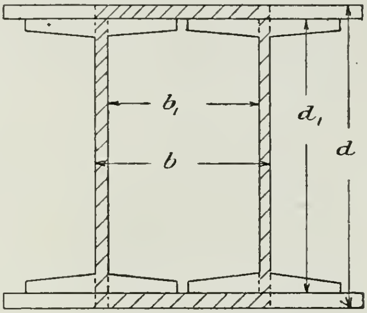


Fig. 2.

It is hoped that some more information upon the strength of I sections against torsion may be forthcoming shortly. Another point which is of great importance is the stress at the junction of the web and flange. There will be, due to the beam action, an appreciable normal stress in the material at this point, and we suggest that for calculations the torsion stress at this point be assumed equal to one-half that at the mid-point of the web.

Numerical Examples.—We will apply these results to a case which may often occur in practice—viz., a 12 in. by 6 in. by 44 lb. I beam of 12-ft. span, which carries at its centre a 10 in. by 5 in. by 30 lb. I beam, transmitting a load of 5·5 tons through the typical cleat connection shown in *Fig.* 1.

The cross-sectional area of the 12 in. by 6 in. by 44 lb. beam is 12·94 sq. in., and the web thickness is ·4 in. The load of 5·5 tons is transmitted at a distance equal to 3·57 from the centre-line of the 12 in. by 6 in. beam, and we may assume that half the resulting torque is carried at each side of the joint.

$$\therefore \text{ Torque on } 12 \times 6 \text{ in. beam} = \frac{5\cdot 5 \times 3\cdot 57}{2} = 9\cdot 8 \text{ in. tons approx.}$$

∴ By Bach's formula.

$$\text{Maximum torsion stress in web} = \frac{4\cdot 5\,T}{A\,t}$$

$$= \frac{4\cdot 5 \times 9\cdot 8}{12\cdot 94 \times \cdot 4} = 8\cdot 5 \text{ tons per sq. in. approx.}$$

---

* "Elasticität und Festigkeit" (Springer, Berlin), 1911, p. 329.

The direct shear stress, assumed uniformly distributed over the web $=\frac{5\cdot5}{2\times\cdot4\times10\cdot5}$ $=\cdot66$ tons per sq. in.

∴ Combined shear stress at the centre of the web $=9\cdot1$ tons per sq. in. approximately.

This is nearly 1·7 times the stress allowed under the L.C.C. Building Act 1909 Amendment, yet we believe that every district surveyor would pass the construction. The matter is sufficiently serious to demand the attention of structural engineers; either they should show the fallacy of the formula in question or they should allow for the torsion stresses in their designs. More extensive experiments upon the subject seem to be essential.

Compound Beams and Box Girders.—The torsional strength of the typical compound beam, consisting of two *I* beams with plates riveted at top and bottom, is not known exactly, but it is known that the projecting portions add but little to their torsional strength, and Messrs. Gibson and Ritchie suggest the section be regarded as equivalent to the hollow rectangular section shown shaded in *Fig.* 2. They have investigated experimentally the torsional deflections given by hollow rectangular sections, and these experiments are in good agreement with the theoretical treatment of the subject.

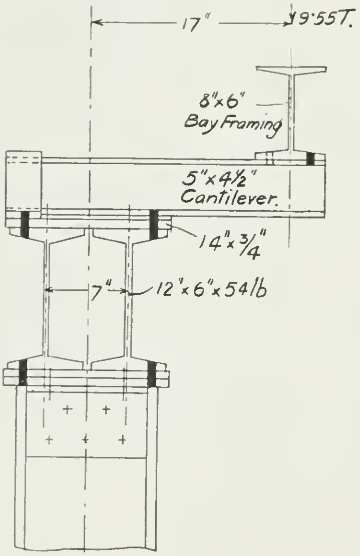


Fig. 3

According to Auteureith's theory, which these authors favour, the diagram of torsional stress along the webs and flanges is a parabola, the maximum stress occurring at the mid-points of the web and flange.

According to this theory we have:

Maximum torsion stress in web =

$$\frac{36\,T}{A\,b\{7\,(1+\gamma^2)-2\,\gamma^4\}} \qquad (4)$$

$$\text{where } \gamma=\frac{b_1}{b}.$$

Maximum torsion stress in flange =

$$\frac{36\,T}{A\,\,d\{7(1+\gamma^2)-2\gamma^4\}} \qquad (5)$$

These formulæ assume that the ratio of inner to outer distance measured from the centre is constant, and this will seldom be true in practice; but the effect of the variation will be of minor importance upon the result.

Numerical Example.—As an example of a calculation of this kind arising in practice, we will take the construction shown in *Fig.* 3 of a compound girder carrying as a torsional load the weight of steelwork carrying a bay window. The bay framing passes over the compound beam at the ends, and at the bends of the frame is connected back to the beam by means of cantilevers. The loading on the compound beam is shown in *Fig.* 4. The load transmitted down each pillar to the bay framing is 9·55 tons, and its torsion arm is 17 in.

$$\therefore\ T = 17 \times 9{\cdot}55 = 162 \text{ in. tons.}$$

The value of A for the equivalent box section is $2\,(12 \times {\cdot}5) + 2\,(\frac{3}{4} \times 7{\cdot}5) = 23{\cdot}2$ sq. in.

$$\gamma = \frac{6{\cdot}5}{7{\cdot}5} = {\cdot}867.$$

$$\frac{36}{7\,(1+\gamma^2) - 2\gamma^4} = \frac{36}{11{\cdot}1} = 3{\cdot}24$$

$$\therefore \text{ Maximum torsion stress in web} = \frac{162 \times 3{\cdot}24}{23{\cdot}2 \times 7{\cdot}5} \text{ (by equation 4)}$$

$$= 3 \text{ tons per sq. in. nearly.} \qquad (6)$$

$$\text{Maximum torsion stress in flange} = \frac{3 \times 7{\cdot}5}{12}$$

$$= 1{\cdot}87 \text{ tons per sq. in.} \qquad (7)$$

Each reaction $= 39{\cdot}1$ tons, $\therefore$ taking the web area $= 2 \times {\cdot}5 \times 10{\cdot}5 = 10{\cdot}5$ sq. in.

$$\text{Direct shear stress at end} = \frac{39{\cdot}1}{10{\cdot}5} = 3{\cdot}72 \text{ tons per sq. in.}$$

$\therefore$ Combined shear stress at end $= 3 + 3{\cdot}72$ = say, $6{\cdot}7$ tons per sq. in. Upon the theory that we have at present under consideration, therefore, the combined shear stress is excessive at the end.

Next let us consider the combined stress due to torsion and bending moment at the points where the cantilevers run in. The bending moment at these points = 104 ft. tons, and the section modulus of the beam section is 210.

$$\therefore \text{ Bending stress} = f = \frac{104 \times 12}{210} = 5{\cdot}94 \text{ tons per sq. in.}$$

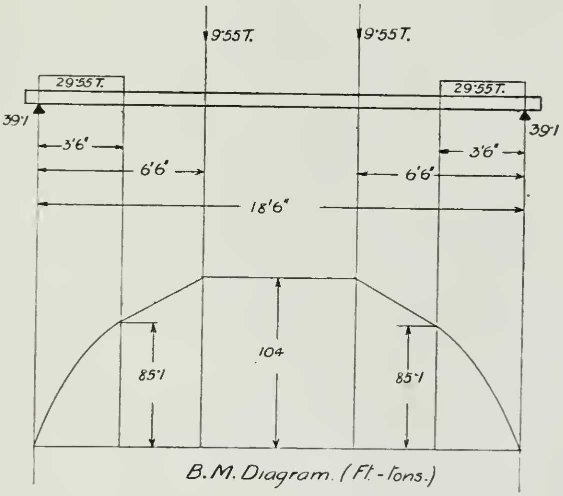


FIG. 4.

By result (7) above we have that the maximum torsion stress in the flange at this point $= s = 1{\cdot}87$ tons per sq. in., the direct shear stress being zero. Adopting St. Venant's formula for compound stresses, we have:

$$\text{Equivalent tensile stress} = \frac{f}{2}\left\{\frac{3}{4} + \frac{5}{4}\sqrt{1 + \frac{4s^2}{f^2}}\right\}$$

$$= \frac{5{\cdot}94}{2}\left\{\frac{3}{4} + \frac{5}{4}\sqrt{1 + \frac{4 \times 1{\cdot}87^2}{5{\cdot}94^2}}\right\}$$

$$= \frac{5{\cdot}94}{2}\left\{{\cdot}75 + 1{\cdot}48\right\}$$

$$= 6{\cdot}6 \text{ tons per sq. in. nearly.}$$

This is within the stresses allowed by the L.C.C. Building Act.

The above numerical examples illustrate the importance of making beams, which have to resist torsion stresses, of box section rather than of a section having single webs.

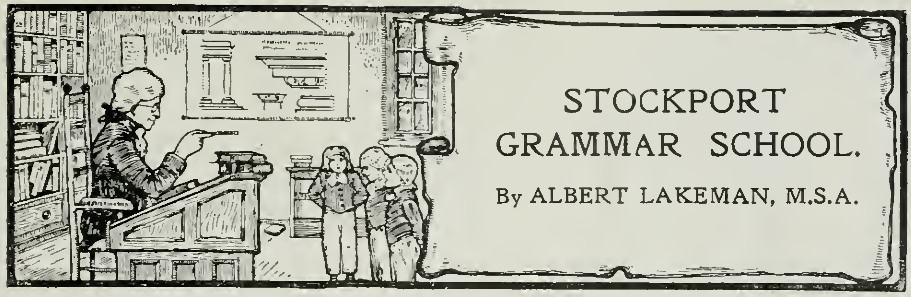
APPLICATION TO GIRDERS CURVED IN PLAN.—It will be noticed from the previous article dealing with the subject that the general formulæ for the changes of slope depend upon I_p, the polar moment of inertia of the beam section. In the two simplest cases of loading which are dealt with in that article this quantity does not appear in the resulting equations for the torsion and bending moments at any point, but in other cases for which diagrams are given in Messrs. Gibson and Ritchie's book the values of I_p must be known before these quantities can be determined.

Now the value of I_p which must be taken is not that given by summing the ordinary moments of inertia about two centroid axes at right angles, but the *effective* polar moment of inertia which can be obtained only by experiment. In the book a table is given (p. 56) of coefficients for obtaining this quantity for box sections for various ratios of depth to height. For the ratio commonly adopted in practice for plated compound *I* girders this coefficient may be taken as about ·7.

One interesting result of Messrs. Gibson and Ritchie's experiments is that by filling a hollow rectangular section with cement the torsional resistance is not greatly increased; in one case the increase was roughly 5 per cent., and in another it was roughly 18 per cent.

It is to be hoped that the experimental work upon this subject will be extended. We should like in particular to know the torsional strength of the shallow *I* beam sections, such as the 15 in. by 5 in. by 42 lb., and the American section 10 in. by 4·66 in. by 25 lb. Our numerical example of the cleat connection shows that the only theory that we have to go upon indicates that excessive stresses are caused in the web in this case; this point ought certainly to be investigated by experiment.

This case may be regarded as an example of secondary stress, but it is not a secondary stress of the kind which disappears by the yielding of the material, and so the "give" of the material which practical designers are very fond of relying upon—rightly in some cases—will not solve the difficulty in this case.



STOCKPORT GRAMMAR SCHOOL.

By ALBERT LAKEMAN, M.S.A.

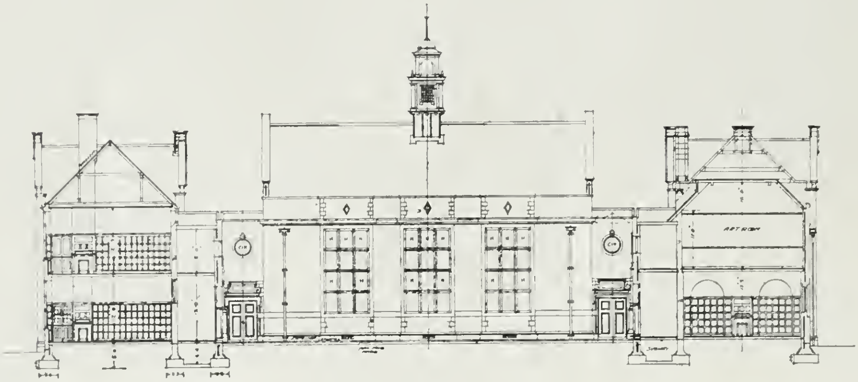
Although not wholly a reinforced concrete building, it will be seen from the following notes that this method of construction was most usefully applied for certain parts of the work.—ED.

THESE school buildings, which have been erected from the designs of Messrs. Spalding and Theakston, FF.R.I.B.A., Architects, King Street, Cheapside, contain a large amount of reinforced concrete construction in the floors, beams, and roofs. The site is a large one, situated on the south-west side of Buxton Road, and as the buildings lay back some distance from this road a private roadway 35 ft. wide was formed right through to the front of the main wing which adjoins the playing fields on the south-west side. The main block of buildings cover an area practically 145 ft. by 230 ft., consisting of four wings surrounding a central court 80 ft. by 60 ft., and in addition to this the work includes fives courts, cycle house, lavatories and large exercise ground.

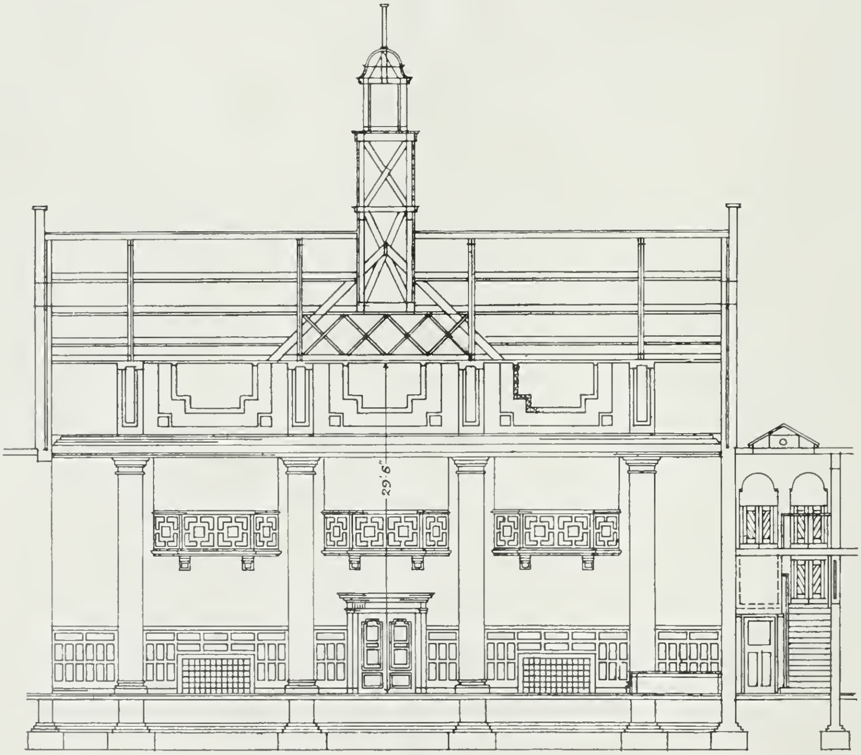
The main entrance for visitors is situated in the south-west wall of the main wing above mentioned, and, after passing through the vestibule, a corridor is reached which adjoins and runs parallel with the Assembly Hall, the latter being 59 ft. long and 30 ft. wide, with a platform at one end and a space for an organ at the other. This Assembly Hall is a fine apartment, with a height of 29 ft. 6 in. to the highest part of a curved ceiling, and a feature is provided externally by a flèche which springs from the centre of the roof. Immediately behind the Assembly Hall is the central court, which has an open corridor on the opposite side, this central space being utilised as an open Quadrangle, with access from all the adjoining corridors and rooms. The ground floor of the north-west wing is devoted to the governor's room, head-master's room, library 31 ft. long, dining room 30 ft. by 25 ft., and general offices with service and living accommodation for the Caretaker at the extreme north-east end. The south-east wing is given up to class rooms, each arranged to take twenty-four boys, and behind this is a projecting block, which includes a gymnasium 50 ft. by 30 ft., swimming bath 58 ft. by 35 ft., and a workshop 35 ft. by 20 ft., in addition to cloak and changing rooms, lavatories, etc. The north-east wing is given up to masters' and boys' common rooms and lavatory accommodation. A small basement is constructed under one portion of the building to contain the heating chamber and coal store.

The first floor plan is taken up with class rooms, lecture theatre, laboratories and art room, and the upper parts of the large apartments which extend through the height of two floors, while galleries are arranged to overlook the assembly hall and gymnasium from the first floor level. The general plans, sections and elevations are illustrated, and the architectural planning and treatment can be fully appreciated upon looking at these drawings.

The reinforced concrete was designed and executed for the architects by

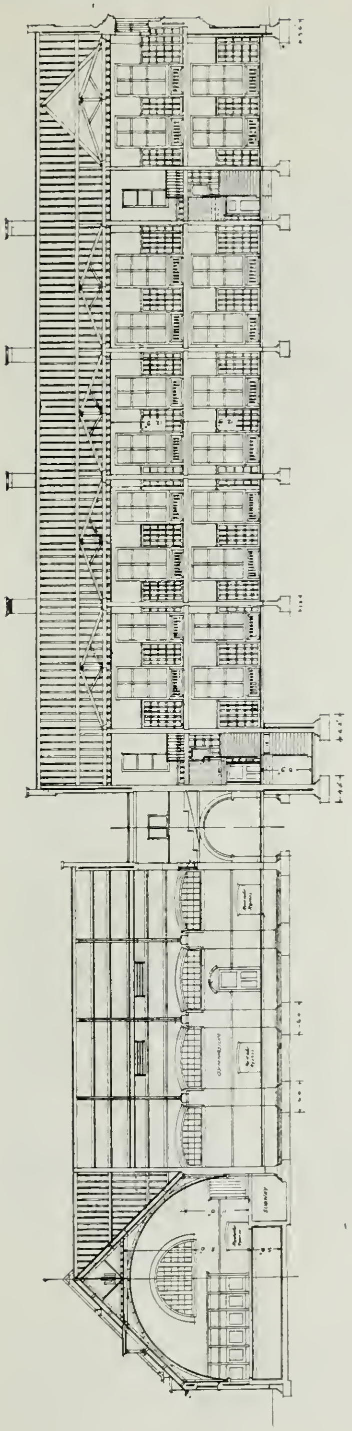


Section BB.



Section HH.
Stockport Grammar School.

Messrs. Stuart's Granolithic Co., Ltd., of 45, Bedford Row, W.C., and although there is nothing of exceptional interest in the concrete members a few notes as to the application of reinforced concrete to a school building



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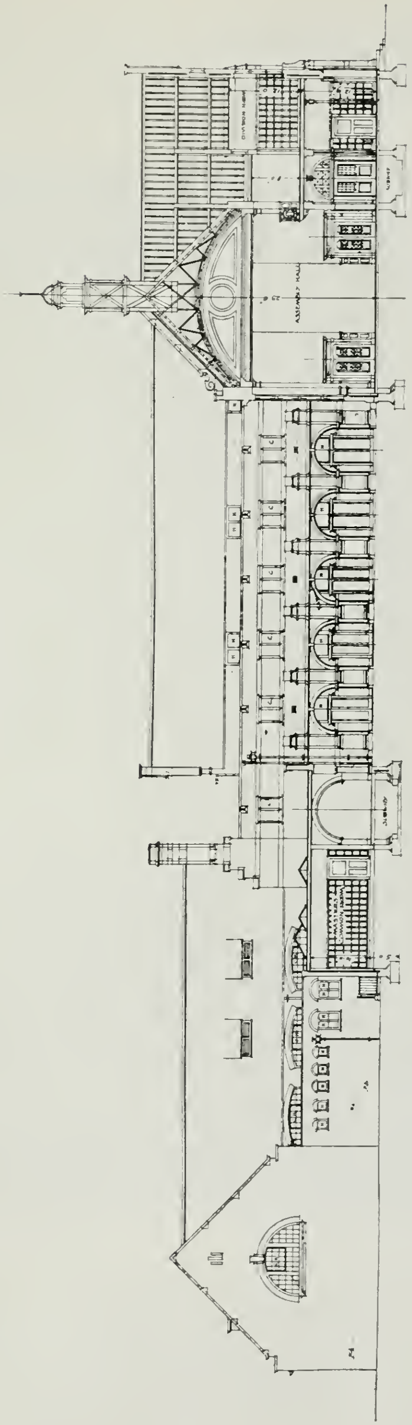
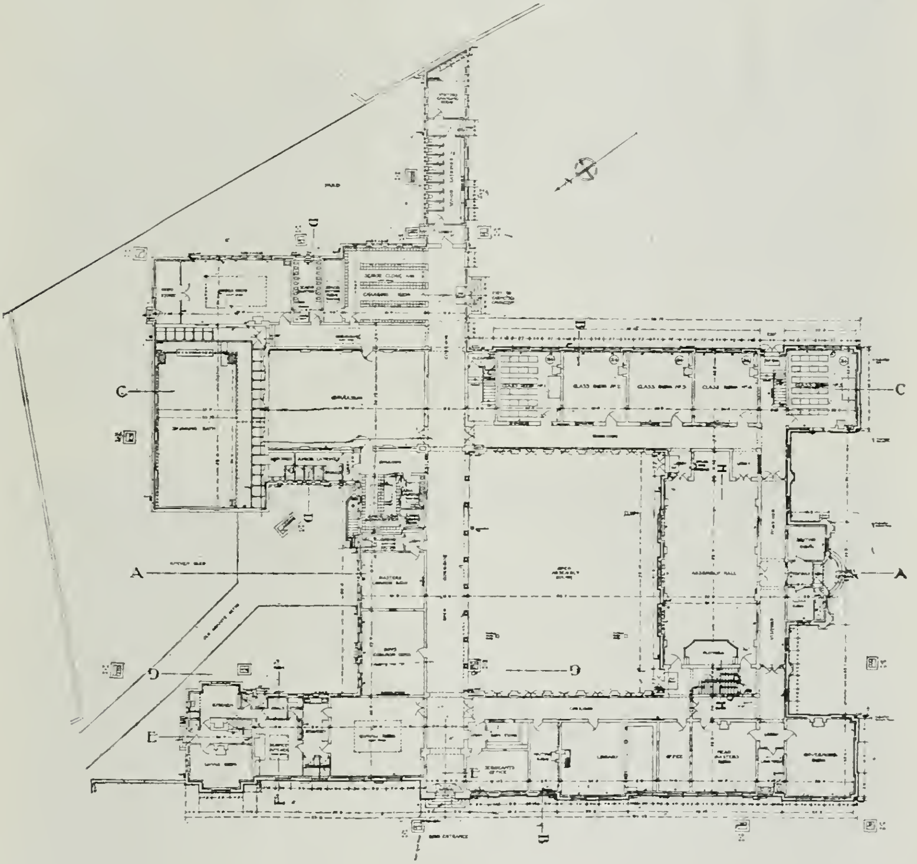


Section AA.
Stockport Grammar School.

should be worthy of notice. The floor over the basement and the pipe ducts, which are arranged under the corridors, is constructed with 4 in. and 5 in. slabs reinforced with $\frac{3}{8}$ in. rods and $\frac{1}{4}$ in. distribution bars. Only a few small beams were used, as no large spans were required; but special backbone rods were introduced in certain positions in the slabs where extra strength was required. Owing to the great length of the corridors, the slabs in this portion were cut up into lengths of about 12 ft. by cross joints, and the slabs between these joints were laid alternately. The floors at the first floor level generally

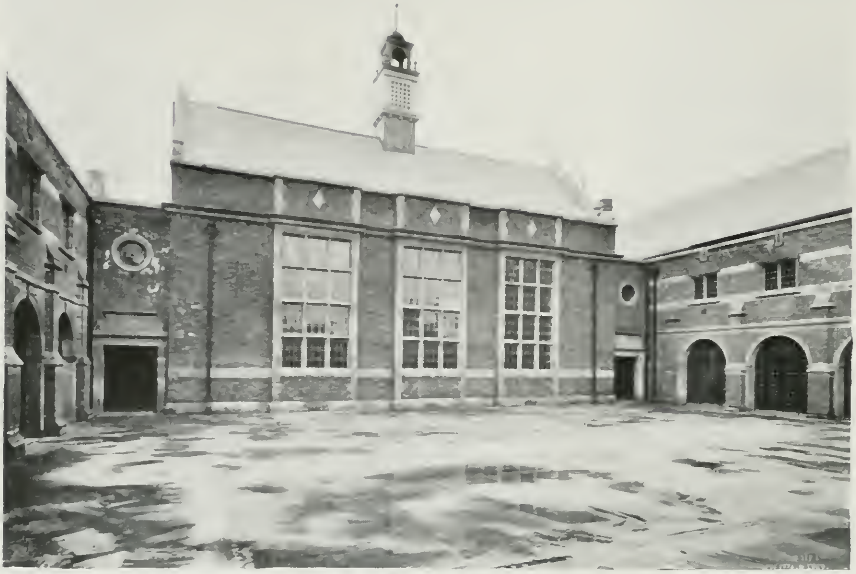
The Assembly Hall.
STOCKPORT GRAMMAR SCHOOL.

are constructed of reinforced slabs 5 in. thick, carried by beams at about 7-ft. centres. The majority of these beams have a span of about 20 ft., and they are 12 in. deep and 7 in. wide, with two $1\frac{3}{8}$-in. rods as main reinforcement, and the largest employed is 19 in. by 9 in., with four $1\frac{1}{4}$-in. rods in the lower surface. All these beams are designed as tee beams, and rods are provided in the upper surface of the slab as transverse reinforcement to the flange. The balconies, which project from the corridor into the large assembly hall, are formed by a continuation of the floor slab with additional rods in the upper surface which are carried out to the end of the projection, bent round and carried back in the lower surface.

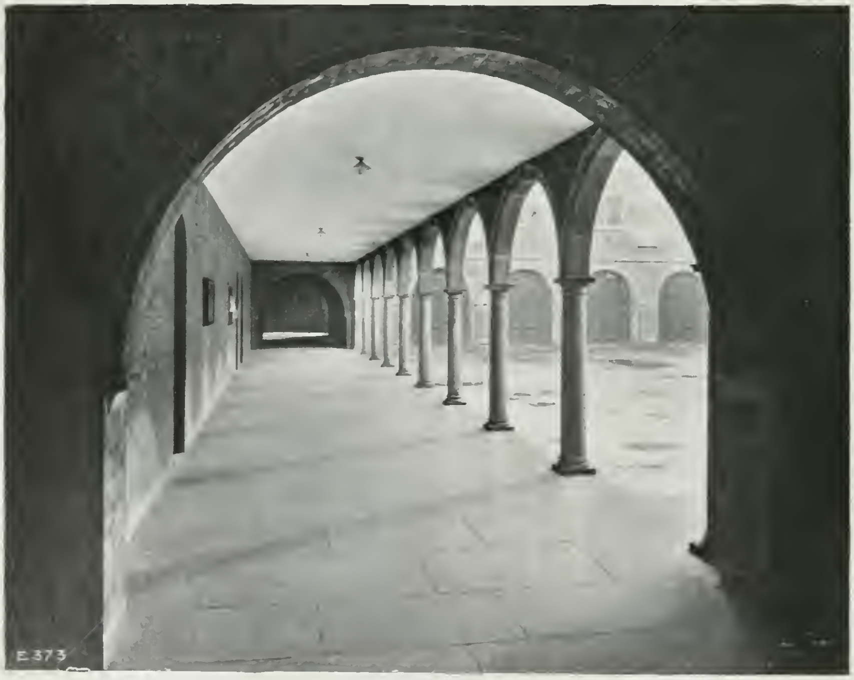


Ground Floor Plan.
Stockport Grammar School.

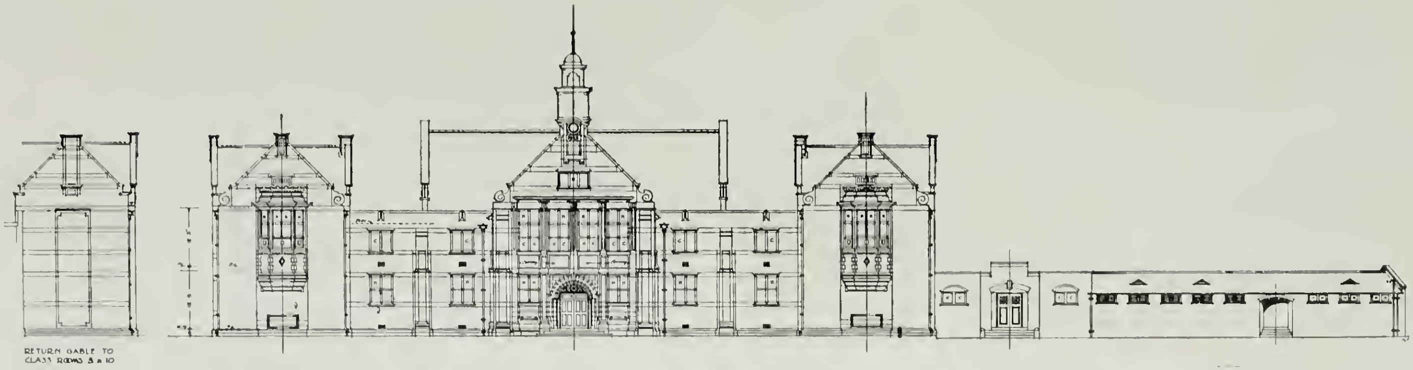
The flat roofs generally are constructed with 4-in. slabs, and where skylights occur the trimming beams are kept up above the flat level to form a kerb 6 in. high, upon which the light is placed. The roof over the art room is carried out with a central flat portion and two sloping sides at an angle of 45 deg., lights being formed in these slopes. The top of the slopes and the central flat are supported by two beams, which each have a length of about



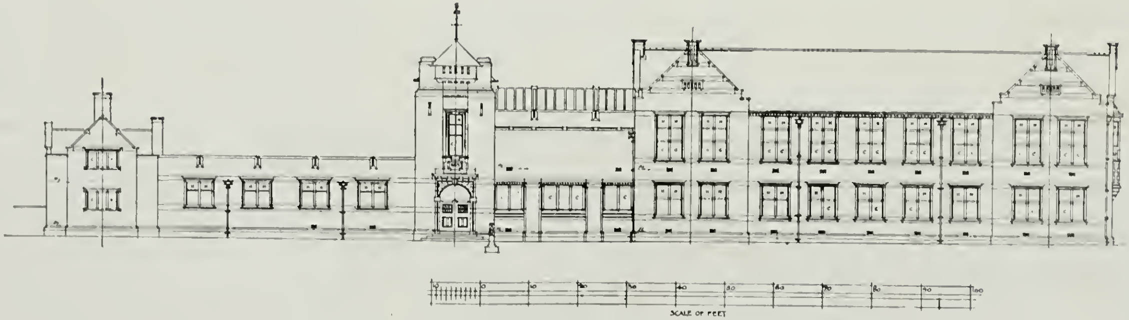
Exterior View.



The Quadrangle.
THE STOCKPORT GRAMMAR SCHOOL.

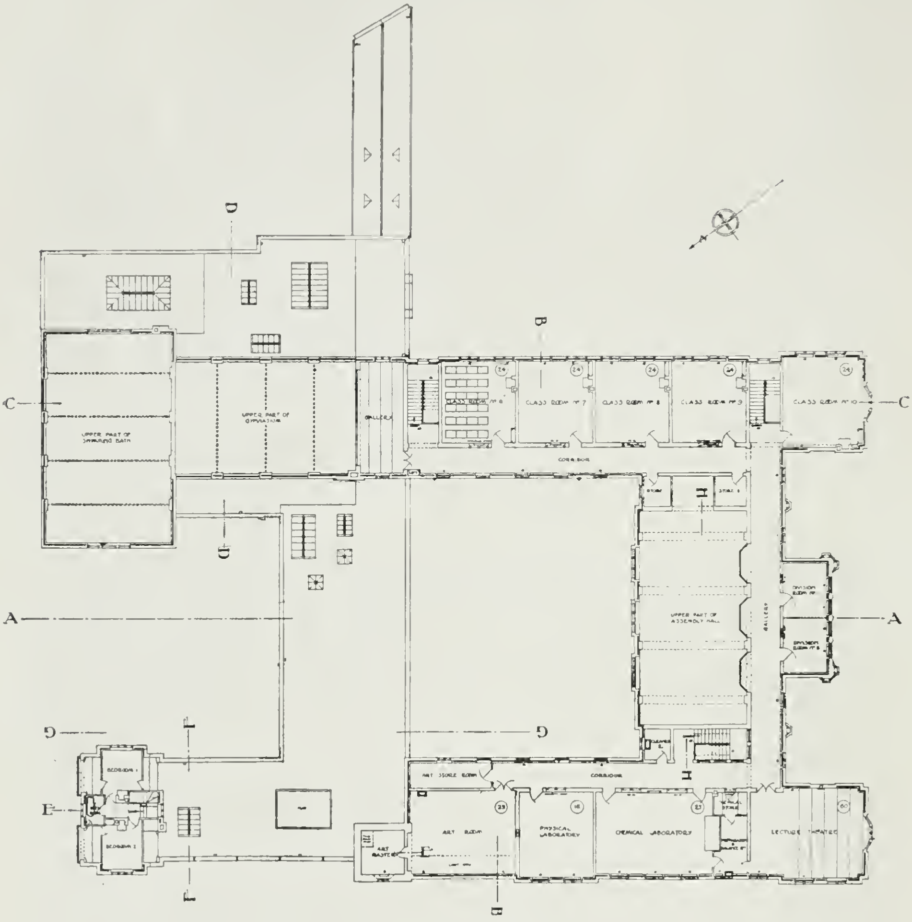


South-west Elevation.



North-west Elevation.
Stockport Grammar School

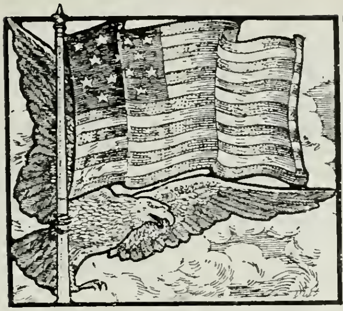
30 ft., and these are 25 in. by 9 in., with three rods in both upper and lower surfaces. Two raking struts, which follow the line of the roof slope, occur under each beam, and these are 8 in. by 6 in., with two or four rods as reinforcement according to the position. The central flat is 5 in. thick, with $\frac{3}{8}$-in. rods at 4-in. pitch, and the sloping sides are 4 in. thick.



First Floor Plan.
STOCKPORT GRAMMAR SCHOOL.

The concrete employed generally was mixed in the proportions of 3 : 2 : 1, and the hangers and bonders were $1\frac{1}{2}$-in. by $\frac{1}{16}$-in. hoop steel. All the $4\frac{1}{2}$-in. brick walls were built with cement, and the floors were carried right over all internal walls and a $4\frac{1}{2}$-in. bearing provided on external walls.

The building contractors were Messrs. Dan Eadie and Co., of Stockport.



2,500-TON CONCRETE CRIBS ARE BUILT AND LAUNCHED IN A "SHIPYARD."

Combined Casting Yard and Marine Railway at Victoria Handles Heavy Cribs for Government Piers—Work Progresses Simultaneously on Five Cribs.

We are indebted for the following particulars and illustrations to "Engineering Records."—ED.

THE question of how to launch the heavy concrete cribs for the Government piers at Victoria, B.C., has presented new problems in requiring some method which could safely handle the great weights without interfering with the steady and speedy progress of the work nor exceeding the reasonable cost limit. The first scheme, using a large floating drydock on which two cribs could be cast and launched simultaneously, resulted in failure and was abandoned. Since then an entirely new plan has been evolved and used successfully which permits of the simultaneous construction of five cribs on a solid structure, and provides for launching on marine ways by slow stages so that there are never sudden excessive strains to endanger cribs or structure.

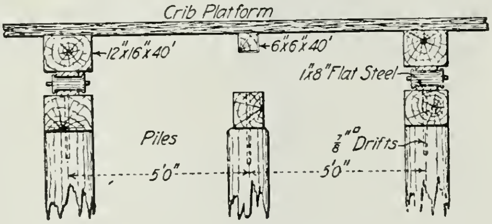


Fig. 1. Details of the Crib Platform.
CONCRETE CRIBS.

The general scheme of constructing the new Government piers requires the construction of fifty-three concrete cribs, for the most part 80 by 35 ft. in plan, 39 ft. high and weighing about 2,500 tons each. The first two of these cribs, constructed on the drydock, were found to be intact after the accident that occurred at the launching, and were later towed to the pier site and properly placed. The marine-way scheme for handling the cribs was then adopted and the first crib launched from the ways on September 25, 1915. This was followed by another on September 30, and still another on October 8, all of which were launched without the slightest hitch. With the plant well under way and in regular running order it is expected that it will be possible to launch a crib every seven days.

BUILDING THE "SHIPYARD."

Each of the cribs, when floating, draws 27 ft. of water, and in order to secure the necessary depth of water in a place well sheltered from storms, it was found best to construct the plant entirely on pile foundations. The most favourable location was in Esquimalt Harbour, about six miles from the pier site. At this point the water is about 40 ft. deep at high tide and the bottom

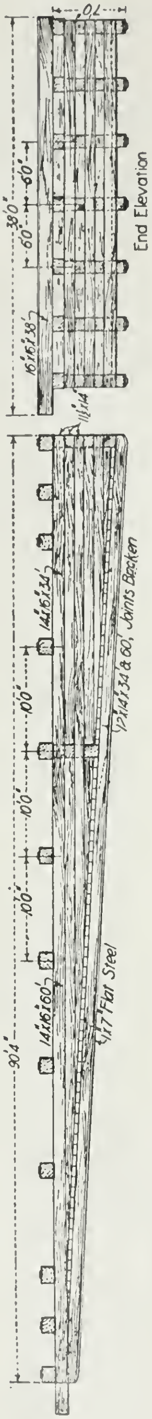


Fig. 2. Launching Cradle, built of timber and filled with gravel ballast to overcome its buoyancy.

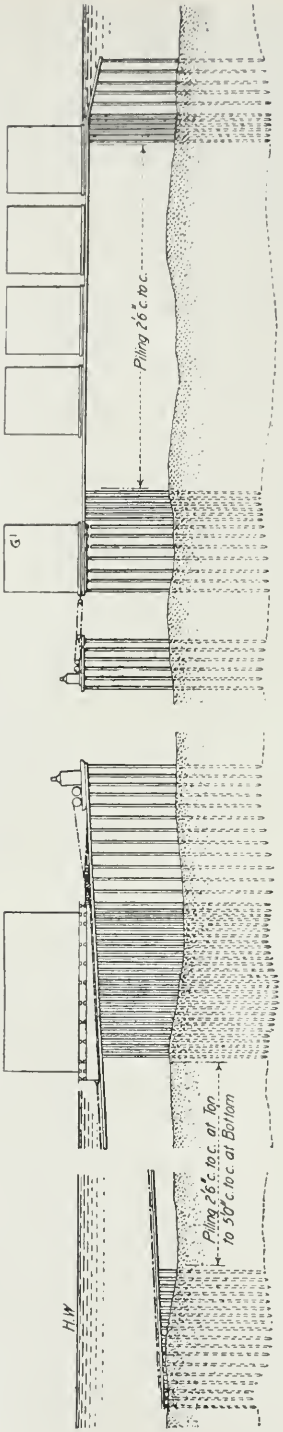


Fig. 3. Engines Cross-Haul Crib and Platform on skeleton wharf and lower down 700 ft. marine-way.

Concrete Cribs.

is mud and clay to a depth of from 45 to 60 ft., at which level bedrock is found. Construction of the plant was started here in February, 1915.

In order to have room for the simultaneous construction of five cribs it was decided to construct a skeleton wharf 90 by 225 ft. in plan. This wharf consisted principally of twelve parallel rows of piling capped with 12 by 16-in. timbers. The rows were spaced 10 ft. apart, except the two outer rows, which were on 4-ft. 9-in. centres. The piling in each of these rows was driven on approximately 2½-ft. centres. Only large Douglas-fir piles with the bark on were driven, and the average length exceeded 100 ft. Under the wharf a strong cross and sway bracing of 3 by 10-in. plank was used. On each of the 12 by 16-in. caps in this skeleton wharf a track of 1 by 8-in. iron was placed and held in position by ⅝-in. countersunk driftbolts.

Five construction platforms 40 by 100 ft. in plan were built with parallel bottom timbers spaced the same as the caps of the skeleton wharf. The platform timbers thus furnished a bed for 1 by 8-in. iron tracks, which corresponded with the tracks on the skeleton wharf over which they moved on twelve rows of cast-iron rollers. These rollers are 4 in. in diameter and have flanges on each end to fit over the 8-in. iron tracks, as shown in one of the accompanying drawings. They are spaced on 10-in. centres and held in position in wooden frames in nests of ten rollers each.

When the platforms are in position on the wharf the top planking is 6 in. above high water and the cribs are constructed directly on them. A layer of roofing felt is laid on the platform prior to the beginning of work on each crib. This prevents the concrete from adhering to the platforms.

MARINE RAILWAY.

The marine-way for launching the cribs is at one end of the skeleton wharf and at right angles to it. The track is 700 ft. long and has a grade of 1 in 18. It consists principally of seven rows of timbers constructed on piling, tied together with cross timbers and carefully braced. Additional support is furnished by batter piles placed along the outer piling of the structure proper. The piles in the incline are all selected Douglas fir and are driven on 2½-ft. centres at the top of the track. They are gradually spaced wider apart toward the lower end of the track, where the buoyancy of the water reduces the weight of the crib. The piles were cut off under water on the required batter by a specially designed circular saw operated from the surface.

A 7-in. iron track for rollers is placed on top of each of the seven lines of timber. It is 1 in. thick at the upper end and gradually reduces to ⅝ in. at the bottom. The track is spiked to the timbers with ⅞-in. driftbolts.

The launching cradle is built of timber as shown in one of the drawings and is filled with gravel ballast to overcome its buoyancy. It moves up and down the incline on seven rows of 4-in. rollers with spacings varying from 10 in. between centres at the upper end of the track to 14 in. between centres at the lower end, where the buoyancy of the water lessens the weight of the crib. These rollers are held in position in wooden frames coupled together in each of the seven rows. The 16 by 16-in. cross timbers on the top of the cradle are spaced to coincide with the twelve-track timbers of the skeleton wharf, thus allowing the iron tracks on cradle and wharf to connect, so it is possible to roll the successive construction platforms with their respective cribs direct from skeleton wharf to cradle.

This cross hauling of the platform and crib to the cradle is accomplished by means of two sets of six-sheave blocks with $\frac{3}{4}$-in. wire rope, power being

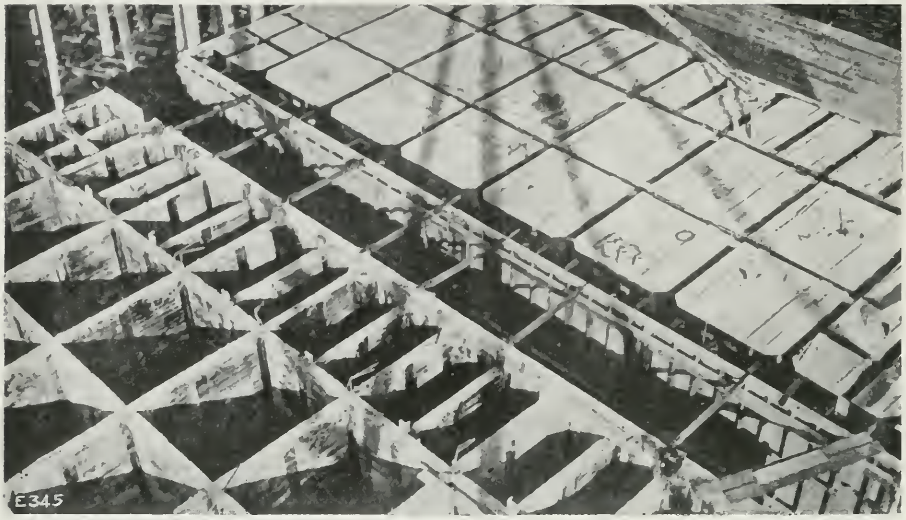


Fig. 4. Inside Forms and Reinforcing Steel of Crib in position.

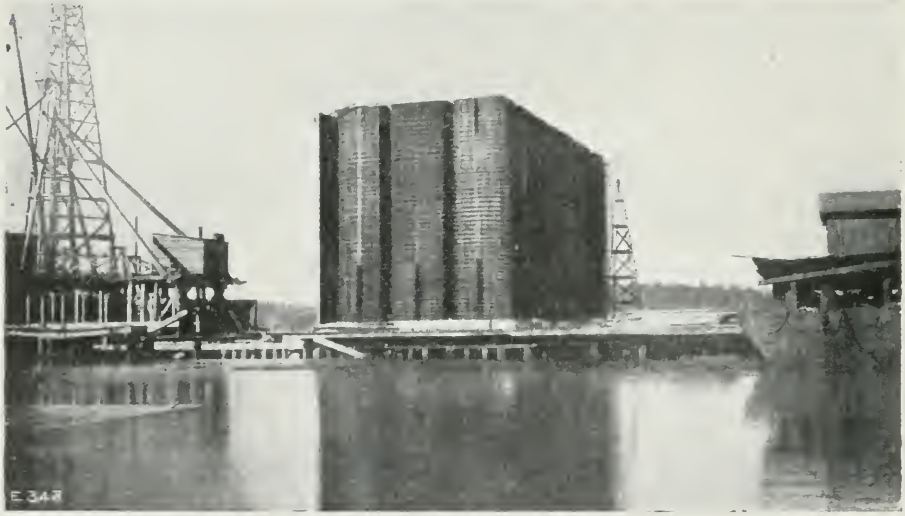


Fig. 5. Finished Crib beside one under construction on wharf.
Concrete Cribs.

furnished by two 7 by 10 hoisting engines. The cradle is held rigid during this time by four 1 by 8-in. steel straps, which are released as soon as the crib is on the cradle, so as to allow the latter to move down the incline.

The rigging for lowering the cradle consists of two 14-sheave tandem blocks, one of which is fastened to the front end of the cradle and the other to the engine bed timbers at the upper end of the launching track. These blocks are reeved with $\frac{3}{4}$-in. and $\frac{7}{8}$-in. wire rope in such a way that the $\frac{7}{8}$-in. rope is in play during the heaviest pull and the $\frac{3}{4}$-in. rope comes into use as the buoyancy and resistance of the water decrease the load. A two-drum highly geared 10 by 12 hoisting engine is used for lowering the cradle.

Owing to the resistance of the water and the power required to overhaul the 14 sheave blocks, the weight of the crib is not sufficient to carry the cradle to the bottom of the incline. A 7 by 10 hoisting engine located alongside the lowering engine furnishes the additional power required to do this. As soon as the first crib is launched, each remaining crib on the skeleton wharf is moved one space nearer by means of the same rigging used to move the completed crib from the wharf to the cradle. The empty platform taken from the crib at the time of launching is towed to the far end of the skeleton wharf and pulled up on the track by means of a short incline. It is then ready to receive the reinforcing steel and forms for another crib.

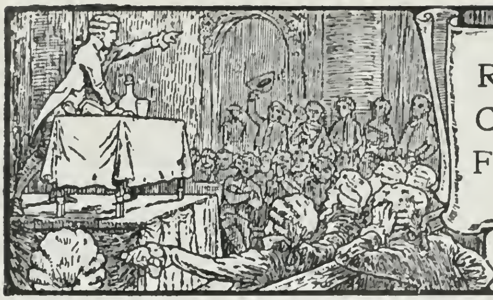
CONCRETE PLANT.

The mixing plant consists of a 1-cu. yd. Smith mixer installed on one end of a 1200-ton scow. Hoppers for sand and gravel were built on the deck to accommodate about 500 cu. yd. of material and were arranged to feed by gravity into measuring hoppers. A 30-in. conveyor belt running underneath the measuring hoppers conveys the sand and gravel to an elevator belt, which carries it to the charging hoppers. The cement is added in the charging hoppers and is handled by compressed air through a 4-in. hose from the cement shed.

The mixed concrete is deposited in the forms by the "open sprouting" method, after being elevated 100 ft. in a tower on one end of the mixer scow. The sand and gravel is delivered from barges to the mixer scow by a derrick operating a $2\frac{1}{2}$-yd. clamshell bucket. The capacity of the plant is 50 cu. yd. per hour. The contractors operate their own hydraulic screening plant in furnishing the sand and gravel.

The numerous longitudinal and transverse bulkhead walls in each of the cribs made it necessary to adopt some type of collapsible inside forms for these bulkhead walls. The method in use and which is working successfully involves the use of sectional unit forms. Each section is so hinged together that when the inside braces are loosened and the form is subjected to a lifting pull it automatically "collapses" and frees itself from the concrete. It is lifted out with a derrick and after the inside braces are replaced in position the form is again ready for use.

The "shipyard" has been constructed by Grant Smith and Company and McDonnell, Ltd., who have the contract for the two Government piers now under construction. The design and construction of the plant was carried out under the supervision of H. W. Bassett, and plans and details were drawn by D. D. Updegraff.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

THE CONCRETE INSTITUTE.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

REINFORCED CONCRETE AS APPLIED TO WATERWORKS CONSTRUCTION.

By CHARLES F. MARSH, M.Inst.C.E., etc.

The following is an extract from a Paper read at the Sixty-sixth Ordinary General Meeting of the Concrete Institute on Wednesday, February 16th.

In the construction of works specially required for the purpose of the conveyance and storage of water reinforced concrete can be usefully employed for many purposes.

The chief uses for this material are the construction of dams for impounding water, of aqueducts and pipes for its conveyance, and reservoirs and tanks for its storage.

There are also many works of an incidental nature for which reinforced concrete may be employed, amongst which are retaining walls, bridges, slope coverings, buildings, fencing, and sundry other structures of various descriptions essential for the completion of any large system of water supply.

Concrete, etc.—The concrete used for structures which must resist the pressure of water should be richer in cement than that used for the generality of structures.

For reservoirs, tanks, and dams, where there is sufficient thickness, the concrete should be mixed in the proportion of 1 : $1\frac{1}{2}$ to 3, or 810 lb. of cement to $13\frac{1}{2}$ cu. ft. of sand and 27 cu. ft. of broken stone or shingle, which mixture is sufficiently watertight for any but very considerable heads, but for pipes and structures of small thickness, say less than 3 in., a mortar mixed in the proportions of 1 to $1\frac{1}{2}$, or 1,620 lb. of cement to 27 cu. ft. of sand, should be used. This mixture is, of course, no more resistant to water pressure than a 1 : $1\frac{1}{2}$ to 3 concrete, but in a thin structure there is a danger in the use of stone or shingle, since two pieces may possibly come together, and any failure in the proper consolidation of the concrete may leave a plane of leakage through the concrete. The size of the broken stone or shingle should not exceed such as will pass through a $\frac{3}{4}$-in. square-meshed sieve, and may with advantage be $\frac{1}{2}$-in. gauge. It is not advisable to use a richer mixture, as rich mixtures shrink more when drying and expand more when wet than leaner mixtures, and consequently cracks are more likely to be induced; while it has been proved conclusively that with proper care in mixing and placing a mixture in the proportions of 1 to $1\frac{1}{2}$ to 3 is practically impervious under considerable heads.

For pipes under pressures exceeding about 40 ft. special linings should be used, such as the sheet steel tubing in a Bonna pipe or other suitable layer of impervious material.

For any structure which has to resist the percolation of liquids it is advisable, in my opinion, to mix some waterproofing compound with the concrete, or otherwise to provide against leakage by the use of a soap and alum wash, paraffin wax, or other suitable protective coating.

For increasing the imperviousness of concrete or mortar ordinary hydrated lime has been used very successfully and appears just as effective as any of the patent compounds on the market. It can be used in proportions up to 10 per cent. of the weight of cement without injuriously affecting the strength of the mixture, but 5 per cent. is sufficient for any ordinary purpose.

The concrete should always be kept damp for some time after moulding, depending on the richness of the mixture. The period in the case of a 1 : $1\frac{1}{2}$: 3 mixture should be about four weeks.

In structures of considerable length, which may be alternately wet and dry and are exposed to the variations of temperature, it is advisable to provide against cracking which is almost certain to occur. Such structure should have specially constructed contraction joints not more than 30 ft. apart, leakage being prevented at the joints by the insertion of sheet lead or copper baffles extending well into the concrete on each side of the joint and bent over at the extremities to form a good key.

In the construction of all structures to resist the pressure of liquids, special care is necessary to provide adequate reinforcement against shrinkage due to the setting of the concrete, fall of temperature, and excessive dryness.

Dams. — Dams for impounding water have not been constructed of reinforced concrete in this country to any extent up to the present time, but there have been many cases in America where this material has been used for such dams.

When reinforced concrete is employed for the construction of dams they are usually of a hollow form of construction, having up-stream and down-stream slabs supported on cross walls carried upon a foundation slab.

From the foundation slab a core wall must be carried down under the bottom of the up-stream slab, and extended well into a watertight stratum. The provision of an adequate cut-off wall is most essential, as some of the dams already constructed of this material have failed owing to the neglect of this precaution.

The up-stream slab is generally constructed with a flat slope not steeper than 1 to 1, since the flatter the slope the more uniform is the pressure on the base.

With a dam of this type, as the reservoir fills, the line of resultant pressure on the base will at first become farther and farther up stream from the centre of pressure on the base with the reservoir empty. When the reservoir has filled for a certain proportion of its depth depending on the slope of the up-stream slab, the line of resultant pressure on the base moves back towards the centre until under the limiting flood conditions it will generally be found to be slightly on the down-stream side of the centre of pressure on the base with the reservoir empty.

The resultant pressure will in no case move very far from the centre of the base, and consequently the intensity of pressure will never vary greatly between the up-stream and down-stream extremities of the base.

In the case of a solid masonry dam the centre of pressure on the base with the reservoir empty is usually at the up-stream extremity of the middle third of the width, and with reservoir under maximum flood is usually at the down-stream limit of the middle third of the width. The consequence of these limits is that with reservoir empty there will be no pressure at the down-stream toe and a maximum pressure at the up-stream heel, while with reservoir full there will be no pressure at the heel with a maximum pressure at the toe. As the reservoir fills the pressure intensity will vary between these extremes.

A further advantage of the hollow type of dam is that the structure is very much lighter, with a consequent reduction of the pressure on the base, whereas with a solid masonry dam the weight of the dam when over a limiting height, depending on the specific gravity of the materials of which it is composed, necessitates an increased widening of the lower portion of the structure in order to keep the pressure within safe limits.

The base slab of a hollow dam is generally formed with holes to allow any water which may gain access under the dam free vent and so obviate any tendency to uplift. The water percolating through the base slab is discharged under the bottom of the down-stream slab to the stream below the dam.

The crest of the dam is formed of such shape as will accommodate the flow of the greatest height of flood which will be allowed to pass over without the formation of a vacuum under the overfall. The down-stream slab is generally constructed of a considerably flatter slope than that usual for solid masonry dams, and the water is consequently conducted to the stream below the dam with less velocity and with a more even flow. This slab frequently terminates before reaching the base of the dam, allowing free access for the water to and from the interior, or sufficient holes are left at its base to effect the same object.

The cross walls or buttresses are stiffened by longitudinal beams, and may be formed with openings to economise material and give means of access.

There is usually a passage-way through the dam from end to end, and frequently several at various depths. The gearing for the outlet and scour valves may be actuated from these passage-ways.

Dams, when of small height, are sometimes constructed without a down-stream slab.

Elevated Tanks.—Perhaps one of the most economical uses of reinforced concrete is in the construction of elevated tanks, of which there are many examples in existence. With care and skill in the design these structures may be made quite picturesque features of the landscape, and are in any case less objectionable than elevated steel tanks on framed supports. A reinforced concrete tank can be constructed at a cost of from 40 per cent. to 50 per cent. that of a tank formed of riveted steel plates, and they will in general be less expensive than tanks of pressed steel or cast-iron plates.

When designing circular reinforced concrete tanks it is, in my opinion, advisable to limit the working resistance of the steel to 12,000 lb. per sq. in., since, although the tensile resistance of the concrete is neglected, the elongation of the steel bars must induce elongation in the concrete, and a higher stress in the steel will in all probability cause the concrete to crack. It is also, in my opinion, advisable to insert two series of circular rings in the walls of the tank, one near each surface, in place of one series at the centre of the thickness. One case has occurred to my knowledge, and there may have been others, where the concrete outside the central series of hoops broke away and caused the failure of the structure. It must be remembered that whereas the interior of the tank is kept at a fairly constant state of moisture and temperature the outside is exposed to the variations in temperature and humidity, and consequently the two surfaces are under very different conditions affecting the expansion and contraction of the concrete.

In the construction of tanks it is sometimes the practice to render the inside with sand and cement to which is added a waterproofing compound. Some constructors rely entirely on the imperviousness of the concrete when properly graded, proportioned, mixed, and deposited; others coat the inner surface with some retentive composition such as paraffin wax, while others mix a waterproofing substance in the concrete used in the construction. The proportion of the concrete most generally adopted for the tank itself is about 1 to 1½ to 3, while a mixture in the proportion of about 1 to 2 to 4 is almost universally used for the supporting columns, bracing, and beams, and also for the roof.

Reservoirs Entirely or Partly in the Ground.—In the construction of reservoirs of this nature the question as to the economy or otherwise resulting from the use of reinforced concrete should receive careful consideration before its employment is decided upon. The method of design, if this material is decided upon, will also require careful consideration.

In many cases it is not economical, in my opinion, to use reinforced concrete for the walls or floor, but it is almost universally an economical material for roof construction.

If a considerable portion of the depth is below ground the form of retaining wall construction, with a bottom slab at the back tied to the front slab by ribs, is not an economical form of construction, as the excavations have to be considerably enlarged to accommodate the bottom slab.

A wall designed as a cantilever, supported from the floor of the reservoir, will reduce the excavation, but great care is necessary to provide ample support at the bottom to prevent failure between the base of the wall and the floor when the reservoir is empty.

If the reservoir is covered and the covering can be constructed before an excessive loading is brought upon the walls, the roof beams and similar beams formed in the floor can be constructed to support beams along the top and bottom of the wall, which in their turn support the ends of vertical beams between which the walls of the reservoir can be constructed as slabs with horizontal reinforcements.

The covering usually adopted for reservoirs is of the beam and slab type, similar to ordinary floors, and supported by columns, but small circular reservoirs may be covered with a flat dome in a similar manner to that frequently employed for elevated tanks.

Aqueducts.—Reinforced concrete is a suitable material for elevated aqueducts, a notable example being the aqueduct used to convey water from the Rhone to the Simplon Tunnel works which was designed and constructed by M. Hennebique, and is illustrated in "Reinforced Concrete," by Marsh and Dunn. This aqueduct was nearly two miles long, with a fall of 1 in 830. It was of box section about 6 ft. 3 in. by 6 ft. 3 in., and the side walls were about 4 in. thick, the floor about 4 in. at the sides, increasing to about 6 in. at the centre, and the roof about 3⅛ in. at the sides and 4¾ in. at the centre. The aqueduct was supported on reinforced concrete columns varying from 13 to 19½ ft. in height and placed about 16 ft. 6 in. centre to centre. Expansion joints were left over each support, with a sheet of flexible metal embedded near the outside. These joints were filled in after the first contraction of the concrete.

Open aqueducts built almost entirely above ground level and those for carrying water over valleys may, with economy, be constructed of reinforced concrete, but for those constructed mainly below ground level this material will not be so economical for the same reasons as given in the case of reservoirs.

Pipes.— Pipes under small heads, say up to about 40 ft., may be constructed of reinforced concrete without any special impervious material being embedded in the thickness.

For heads over about 40 ft. some special impervious layer is, in my opinion, necessary. The well-known Bonna pipe is a good example of this type of construction. The impervious layer is formed by a thin sheet steel tube with longitudinal welds formed by the oxy-acetylene or electric processes. This tube is embedded in the thickness of the concrete with the reinforcement outside for smaller heads and inside and outside for greater heads.

Reinforced concrete pipes when of convenient diameter are moulded vertically; the reinforcement and the steel tube, if this is used, are first placed vertically on a staging, a collapsible steel core is then lowered and fixed accurately in position, after which a detachable iron outer mould is placed around the reinforcement and tube.

The concrete is mixed fairly liquid and is poured into the mould from an elevated staging. While the concrete is being poured the outer mould is struck repeatedly with a hammer to consolidate the concrete and drive out the air.

Pipes up to about 4 ft. in diameter are moulded in advance and the joints formed with a reinforced concrete collar. For low pressures the collars are simply run with cement mortar, but for high pressures the joint is made with a steel corrugated ring, into which are driven lead pipes filled with gasket. The collar is then threaded over the joint and run in the usual manner.

Large pipes must be formed *in situ*, and in this case great care must be taken to form a good connection when recommencing the work after a stoppage.

When the pipes are moulded in advance it is advisable to use a quick-setting cement in order that the moulds may be removed without loss of time, so that they may be ready for moulding a fresh pipe as soon as possible.

After the moulds have been removed the pipes are left standing for about five or six days, and are then lowered and left lying horizontally until removed for laying.

The pipes should be kept damp for at least one month after the removal of the moulds.

In designing pipes the stress in the steel should be limited to 12,000 lb. per sq. in., and it is advisable to form the reinforcement with outer and inner spirals when the pipes are of large diameter for the same reasons as given previously with respect to elevated circular tanks.

The thickness of concrete for pipes may be approximately 1 in. per foot of diameter with a minimum of 1½ in.

DISCUSSION.

The President, in congratulating the author upon his interesting Paper, remarked that the illustrations of pipes were probably new to the majority of them. Referring to concrete tube sections, he thought that during transport it might be advisable to provide support against stress, due to their own weight, which very often caused them to crack.

Mr. D. B. Butler, Assoc.M.Inst.C.E., said that the proportions given in the Paper were, as a general rule, 1 to 1½ to 3, which, he understood, was practically the same as 3 to 1 by volume, because the sand being 1½ to 3, the aggregate would all mix into the interstices of the gravel or ballast and make one volume. He took it that the weight of cement was based on a cubic foot of cement weighing 90 lb. 810 lb. of cement would be about four bags of cement, reckoning eleven bags to the ton, so that it would be for that mixture a yard of broken stone, half a yard of sand, and four bags of cement; a very convenient way of mixing. He should like to know whether the author's statement with regard to the use of hydrated lime for increasing imperviousness was based on actual experience.

Mr. Marsh replied that the statement was based upon experiments carried out in America. Personally, he was of opinion that, if concrete were properly graded and mixed, no particular addition was necessary.

Mr. Henry J. Tingle, M.Inst.C.E., desired to know what was Mr. Marsh's experience in dealing with the question of cracks in aqueducts caused by hot weather. In an elevated aqueduct the outer side was exposed to the weather, and the inner side was usually, for anything up to two-thirds of its depth, in contact with water. Were there any instances of pump-wells being constructed in reinforced concrete? Personally, he was not aware of any, but given sufficient diameter in which to work it, he thought it might be a very good thing to use. With regard to water-tightness and the various mixtures of cement, he should think there was no difficulty, under careful supervision and with good materials, and a concrete such as the author had described, in getting tightness with the addition of any watertight preparation up to certainly 20 or 25 ft., but beyond that possibly, if it could be used, some additional proportion would be advisable. There was no doubt in his mind that the Bonna pipe or similar pipes would play a much greater part in the distribution of water under heavy heads than it had succeeded in doing up to the present. The experience in Paris of this pipe had been exceedingly good, both in contact with sewage and water. Pipes of that description, if made in the trench, would require very careful inspection to keep the air out.

Mr. Noel Ridley, M.Inst.C.E., remarked, in connection with water-tightness, that he always felt some timidity in relying solely on concrete without any admixture of material to make it more impervious. He usually rendered his concrete with an admixture of some waterproofing material.

Mr. Ewart S. Andrews, B.Sc. (Eng.), observed, with regard to the design of the reinforcement of water towers, that Mr. Marsh's point as to the double ring was quite good, because it was almost certain that there would be some bending stresses developed, due possibly to the pipe not being a complete and perfect circle. When bending stresses were developed, they might work in every direction; therefore it was necessary to have some reinforcement on the sides.

Mr. W. A. Green, M.A., asked if it was the custom to have the bottoms of the water tanks dome shaped, as shown in the Paper, or did they ever have an inverted dome, following on the lines of a steel tank? Was that the most common form of construction?

Mr. Marsh: All forms are used; the form I have given is frequently used, but sometimes they have flat bottoms and sometimes inverted domes.

Mr. S. Bylander (Past-Chairman, J.I.E.) inquired whether any difference had been found in the effect of placing the reinforcements far apart or close; had that affected the water-tightness of the slab considerably on account of uneven distribution of stress?

Mr. E. Lawrence Hall, A.R.I.B.A., referring to the author's statement that a certain concrete was found absolutely watertight without any admixture of patent compound, asked what were the correct proportions of the concrete?

Mr. Marsh: As far as I can remember, it was 1 to 1½ to 3.

Mr. W. J. H. Leverton, Lic.R.I.B.A., pointed out that, as lime took longer to set than cement, possibly the mixture of hydrated lime might increase the time in which a thorough setting would take place.

MR. MARSH'S REPLY.

Mr. Marsh, in reply, said that Mr. Butler had brought up the old trouble of 1 to 3. If any proportions were given at all, they ought to be the proportions of the cement, the sand, and the stone. It would probably be a little more than 1 to 3; but 1 to 1½ to 3 was a very well-known mixture. A very good way to proportion the ingredients, when using the weight of cement, was to take, say, 200 lb. bags as the unit and proportion your sand and cement to that, then you could use your bags as your proportioning for the cement. Mr. Butler seemed to think that because, according to the Paper, the concrete was mixed in the proportion of 1 to 1½ to 3 and there was so much care exercised in mixing and proportioning that it did not leak, that was a sufficient reason for never putting in anything to prevent leakage. It was perfectly true that an absolutely well-mixed, well-proportioned concrete, if well placed, would resist these pressures, but there was no reason why an extra factor of safety should not be taken and something put in to help, if it were not quite so good as it ought to be. He thought that some advantage was obtained from adding hydrated lime or something of that sort, because it filled up the pores and gave an extra factor to guard against leakage.

Dealing with Mr. Tingle's remarks regarding cracks, metal baffles were used at the Simplon Tunnel for that very purpose. He was not very greatly in favour of pump-wells being constructed in reinforced concrete. The probability was that you would put in a thicker wall of concrete, or brickwork, which would be more economical than reinforcing it.

He agreed with Mr. Noel Ridley that a good many people rendered. No doubt it was quite satisfactory, but he never cared about rendering, as it flaked off, cracked, and there was always a liability to failure in some way or another.

Repying to Mr. Andrews' point, he agreed that there might be some effect on the sides of the tank in certain circumstances, but in any case it would disappear very soon. It would not affect the sides when you got two or three feet up, but only the very bottom. He thought it was the usual practice to consider the sides of the tank as entirely separate from the bottom and design the reinforcement to take the full pressure of the depth of the water.

In his opinion it was desirable to place the reinforcements close together, and put in smaller ones. It was extremely advisable to put in very heavy rods, and far apart, particularly in the side walls of the tank. You wanted to get as homogeneous a structure as possible.

In his opinion the use of hydrated lime would decrease the setting time; but, in any case, it was only a small percentage, not sufficient to affect the time allowed for the removal of the mould.

MEMORANDUM.

Reinforced Concrete Causeway.— Engineers have long contemplated the sandbanks stretching between India and Ceylon as affording the route for the railway that must ultimately connect the beautiful isle of the Singhalee with the Indian mainland.

But just how to make Adam's Bridge a bridge in fact as well as in name has baffled several generations of engineers. The gap is not as long as it was a few years ago, thanks to recent skilful seaward extensions of the terminal points of the railways. In fact, the break now measures barely twenty miles, since the South Indian Railway has been extended to Dhanushkodi, the Ceylon State Railway meanwhile being brought to Talaimannar, at the opposite side of the shallow strait. Excellent, though these extensions are, the desire is now, as always, to abolish the ferry-boats entirely, and to secure through running trains.

With this object in view, a scheme has been worked out, according to the Administrative Report, whereby a connecting railway line should be laid on a solid embankment to be erected on the sandbank known as Adam's Bridge.

This causeway would extend about twenty miles, of which about seven miles would be built upon the dry land of the various islands, and thirteen miles in water. The section through the sea would be constructed on a double row of reinforced concrete piles driven into the sand, pitched at 10-ft. centres, and having their inner faces 14 ft. apart. These piles would then be braced together longitudinally, with light concrete arches and chains, and transversely with concrete ties, struts, and chains. Behind the piles slabs of reinforced concrete would be slipped into position, the bottom slabs being sunk well into the sea-bottom, and the space enclosed by the slabs filled in with sand. The top of the concrete work would be carried 6 ft. above high-water. The estimated cost of the work is £740,000.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

REINFORCED CONCRETE RETAINING WALL AT QUEEN'S HOTEL, BIRMINGHAM.

During the past few years most of our railway companies have made great alterations and additions to their chief termini and main line stations, and in these reinforced concrete has played a great part.

In some of these works its use has saved thousands of pounds and at the same time allowed valuable space to be saved, and this example at Birmingham is very interesting on that account.

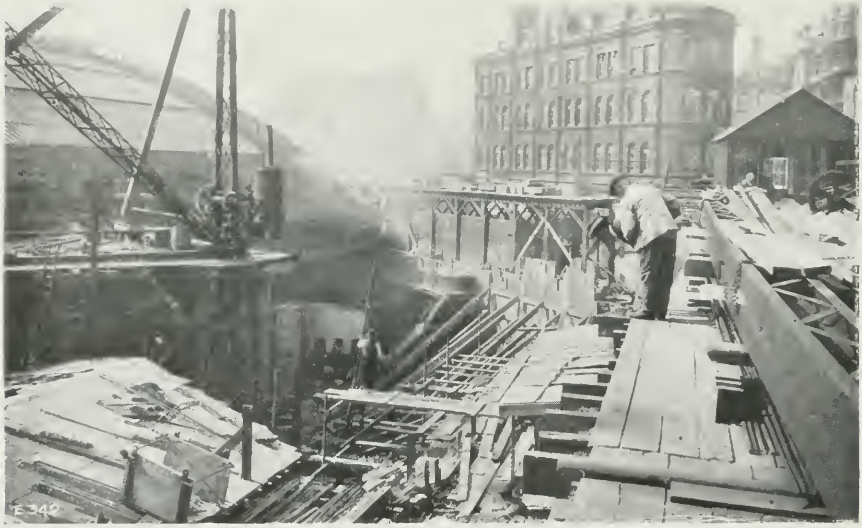


Fig. 1 Showing Retaining Wall in course of construction.
Reinforced Concrete Retaining Wall, Queen's Hotel, Birmingham.

For some time the Queen's Hotel, Birmingham, had been found to be too small for the needs of the traffic, and it was therefore decided to extend it. This extension involved connecting the new building with the old and also with the existing station roof and led to some rather unusual structural work.

At the front of the hotel the street level is about 35 ft. above the lowest basement floor, and a retaining wall of this height was necessary to support the roadway which runs in front of the hotel, and which is subject to heavy traffic. It was also important that the retaining wall should be self-supporting, and that it should be stable before the hotel was built.

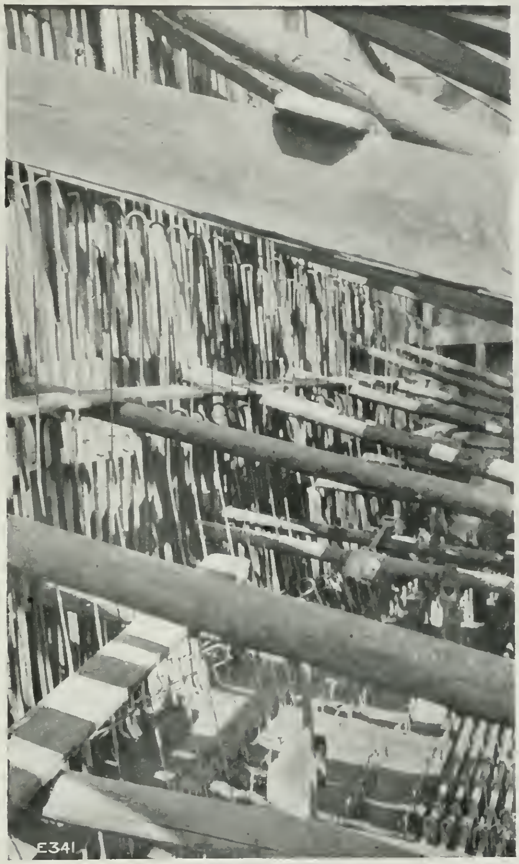


Fig. 2. Showing Reinforcement.

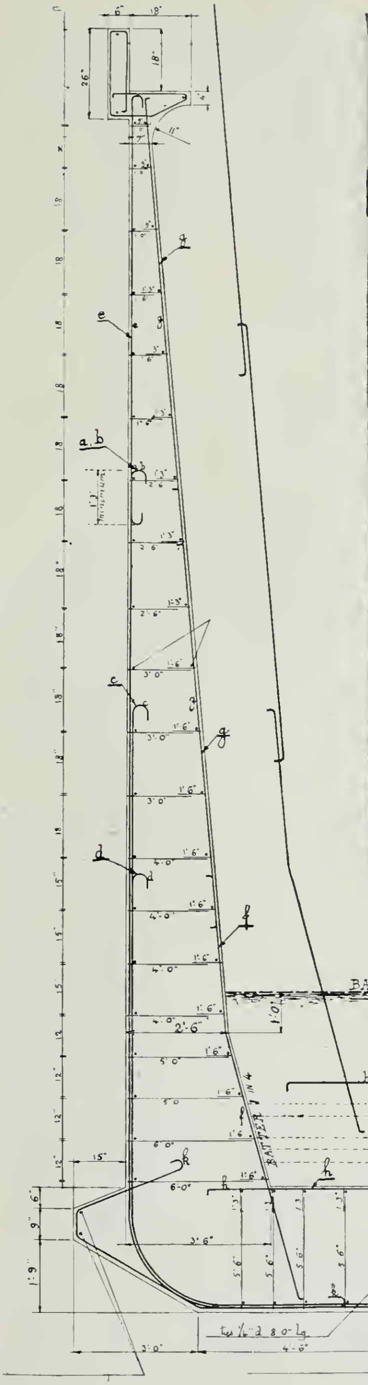


Fig. 3. Vertical Section.

Reinforced Concrete Retaining Wall, Queen's Hotel, Birmingham.

A mass concrete wall would have been of enormous thickness to do the work required and, in order to economise space as much as possible, the architects decided to adopt reinforced concrete.

At one end of the front the wall is only 25 ft. high, and this portion of the work was designed with a wall of uniform section, but at the other end where the full 35 ft. is required counterforts were introduced for economical reasons.

Owing to the comparative lightness of reinforced concrete walls there is always some difficulty in designing them so that they shall possess a proper factor of safety against sliding forward. Buttresses of any form would have interfered with the use of the new building, but the difficulty was overcome by making the base of the wall at the lower end 6 ft. thick and by carrying it out 22 ft. towards the interior of the building.

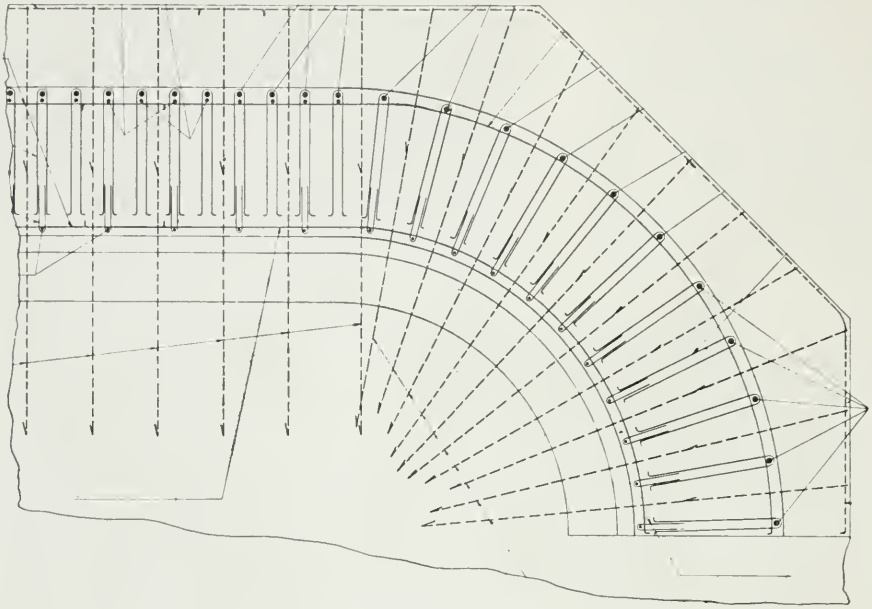


Fig. 4. Horizontal Section.
Reinforced Concrete Retaining Wall, Queen's Hotel, Birmingham

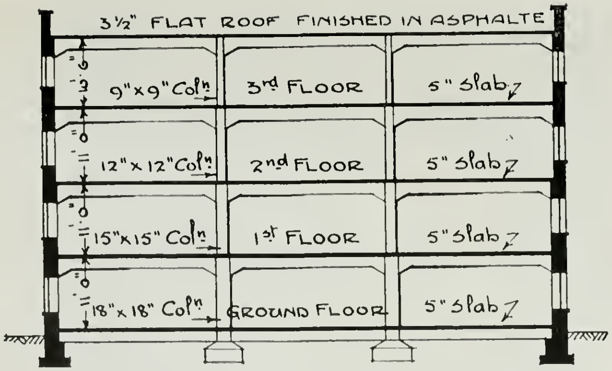
This mass of concrete gives proper security against the wall either sliding forward or overturning. The moment of resistance of the wall as apart from its general stability was made equal to the bending moments resulting from the earth pressures as calculated by Rankine's method, and an allowance for impact was made on account of the very heavy motor lorry traffic which runs on granite setts on the road in front of the wall.

As will be seen from the drawing, the foot of the wall runs under the front of the new building, and this necessitates designing it to receive the loads from the steel stancheons carrying the superstructure over, which load tends also to increase the stability of the retaining wall itself.

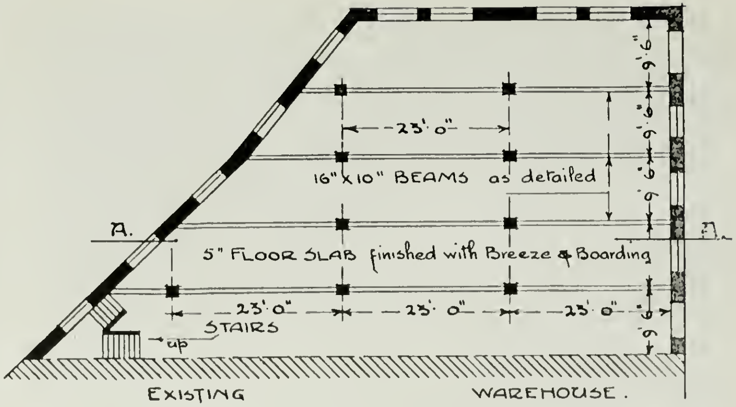
The architects for the work were Messrs. Joseph and Smithem, of 83, Queen Street, E.C., and the whole of this work was carried out by Messrs. James Bowen and Son, the general contractors, to the designs of the Considère Construction Co., of 5, Victoria Street, Westminster.

ROSEMARY MILLS, BRIGHOUSE, YORKSHIRE.

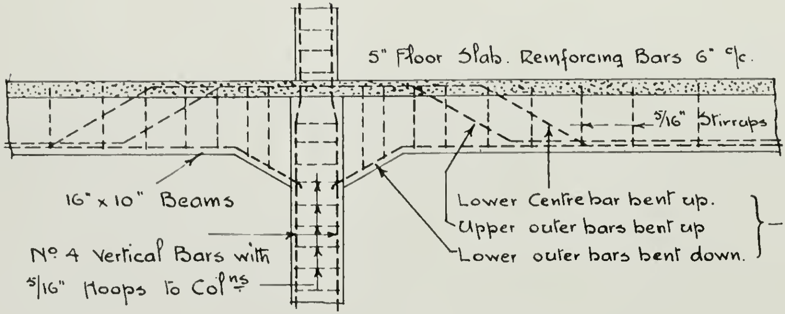
Reinforced concrete is becoming increasingly popular amongst architects and building proprietors in the woollen district of Yorkshire. Apart from its adaptability to mill



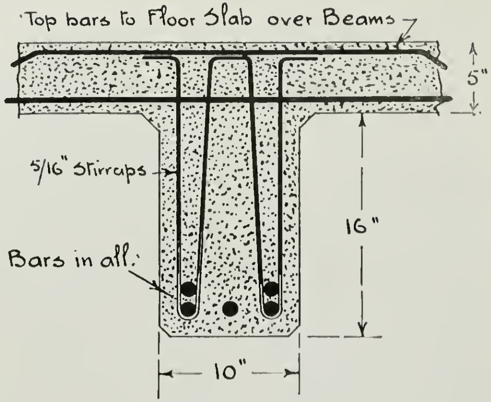
SECTION A.A.



PLAN.



Floor Detail.



Beam Detail.

Rosemary Mills, Brighouse, Yorkshire.

and warehouse structures and the economy effected in construction and maintenance, its fireproof qualities are widely recognised and appreciated by manufacturers and others to whom disorganisation of business, occasioned by the destruction of a building by fire, is a matter of serious concern.

The accompanying illustration shows plan and section of a four-story building recently erected for Messrs. Walshaw Drake, Ltd., of Brighouse, as an extension to existing premises, the additional floor area afforded being approximately 1,400 super yds. The flat roof is also of reinforced concrete finished with rock asphalte.

The construction is of the simplest type, no secondary beams being employed to carry the floor slab, a feature which resulted in facility of erection and economy in cost.

The reinforcement of the main beam is indicated on the enlarged detail. The columns were reinforced by four vertical bars with rectilinear bindings at appropriate spacing.

Lift wells, bulkheads to hoists, stairways, etc., were all constructed in reinforced concrete, the external walls being finished in local stone.

The whole of the reinforced concrete work was executed by Arthur Mitchell (The Chain Concrete Syndicate), of 1, Basinghall Square, Leeds, from designs prepared by Mr. Horace F. Smith, engineer to the Syndicate.

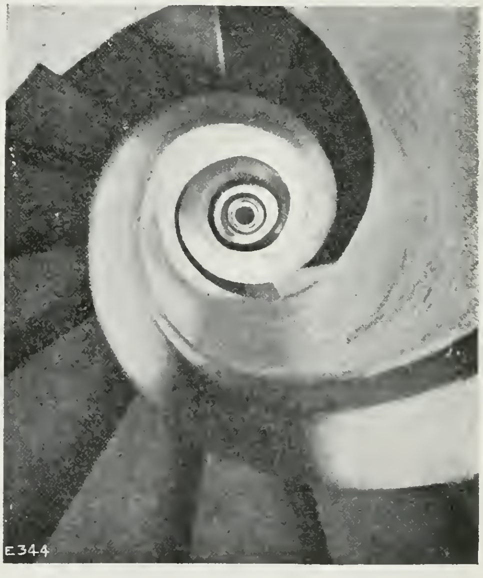
Messrs. Sharp and Waller, of Brighouse, were the architects, to whose requirements and under whose superintendence the whole of the structure was erected.

HELICAL STAIRWAY WITHIN CENTRE WELL.

In an article in the *Engineering Record*, Mr. Frank Reed, of Los Angeles, gives an interesting description of a reinforced concrete helical staircase :—

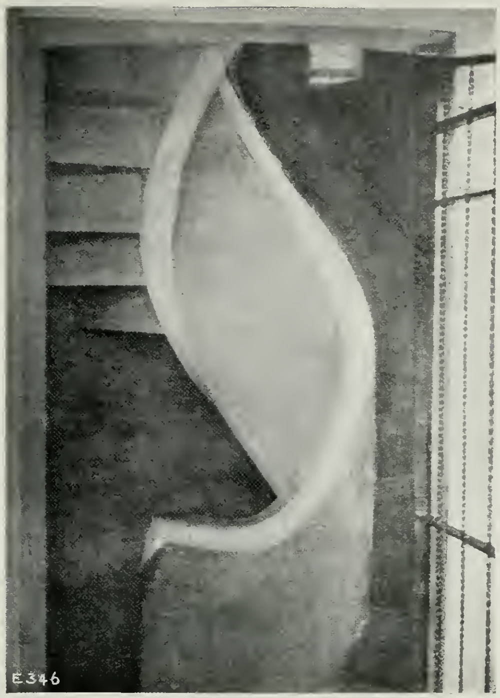
"The tower of the Southwest Museum in Los Angeles, Cal., contains what is believed to be the only helical stairway of its kind built of concrete to be found in the world. It is, for its purpose here, an improvement over Sir Christopher Wren's masterpiece, the spiral stairway ascending the interior wall in the tower of St. Paul's Cathedral, London. The Southwest Museum helical staircase is built inside a well in the centre of the tower, thus not only preserving for shelves or mounted objects the entire interior wall space of the tower, but also supplying on its own exterior wall additional space which may be employed for museum purposes.

"The tower containing the stairway is seven stories in height, with three mezzanine balconies in the three upper stories, giving the equivalent of ten stories. The tower is 35 ft. square, and is supported by twelve columns and external walls 8 in. thick, reinforced with steel. It rests on a solid concrete slab or raft 3 ft. 6 in. thick. The total height is 125 ft. and the weight is 1,000 tons. The construction was carried on continuously, a story being poured at a time.



Top View, showing Four Stories of Stairs.
Reinforced Concrete Helical Stairway.

"***Staircase Well.***—The staircase well is 9 ft. 2 in. in external



View of Stairs from Room in Tower.
REINFORCED CONCRETE HELICAL STAIRWAY.

diameter and is supported by four corner columns with 8-in. walls between them, with light and ventilation openings at each story. The stair is known as a caracol, on account of the likeness to a snail shell presented by a vertical view, as shown in one of the photographs. With one exception it is the only helical staircase in America having a hollow centre, the other one being an ancient stone staircase in the tower of the cathedral in the city of Mexico. The stairway contains 160 steps with $7\frac{1}{2}$ in. rise each, and was built around a galvanised iron form in the shape of a pipe, while wooden forms were placed for the stairs. Material was prepared at a special rock-crushing and sand plant located about one mile from the building, in a dry river bed. The mixture employed was a 1 : 5 concrete.

"Dr. Charles F. Lummis, founder of the Southwest Museum, supervised personally the construction of this stairway. The museum was designed by Hunt and Burns, architects, of Los Angeles, and built by the C. J. Kubach Company of the same city."

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

A Treatise on Hand Lettering. By Wilfrid J. Lineham.

ondon: Chapman & Hall, Ltd. 282 pp.+xii. Price 7/6 net.

This is an excellent book on hand lettering for engineers, architects, surveyors, and students of mechanical drawing, and it has been prepared with the object of giving practical instruction in all types of lettering actually required in the preparation of drawings, posters, and such-like. The author commences with some general useful information on hand lettering, and then proceeds with exercises and examples of various kinds. The work is arranged in the same order as the work should be done to attain efficiency and taking each alphabet in turn, the most useful ones first and the more decorative ones last. The order is as follows :—

1. The outlining of the letters in pencil.
2. The general mode of forming the ink letter.
3. Complete ink alphabet and figures.
4. Formation of continuous sentences.
5. Centralised titles for each particular style.
6. The treatment of complete drawings.

The last-mentioned item is illustrated by several plates which are examples of actual drawings lettered and figured in accordance with actual practical requirements, and the reader is therefore taken through the whole process from the formation of a single letter to the complete lettering of a working drawing. The book is well arranged and produced, and the work throughout is of the highest merit, and the volume is the best we have seen that deals with the important subject of lettering. Many otherwise excellent drawings are spoilt by weak or unsuitable lettering and figuring, and this is due to a proper study not being made by the average draughtsman, and a volume of this standard should be in every drawing office to show the draughtsman therein the class of work required.

A.B.C. Guide to Patents for Inventions (2nd Edition). By Robert E. Phillips and A. Millward Flack.

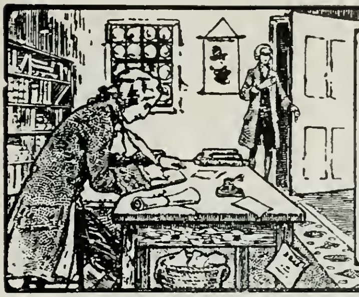
Published by Messrs. Phillipps, 70 Chancery Lane, London, W.C. 66 pp. demy 8vo.

To most engineers who are laymen in patent matters this handbook should be of considerable assistance; it will give them information which should avoid the pitfalls which await the unwary on the paths of patent law and procedure.

The alphabetical arrangement of the book facilitates reference upon any particular point, although the necessary cross-references entail considerable turning up other headings in the hope of finding further information.

The information given in the book is sound, and the make-up of the book is clear and concise; while having no wish to detract from its merits, we will enumerate one or two points in which it might be made more useful. We do not find any statement of the fees to be paid (an important matter for many inventors) although "the prescribed fee" is constantly referred to; nor does there appear to be a reference to the official publication "Instructions to Applications for Applicants," which contains useful information upon the preparation of drawings and other matters and is issued gratis.

Under the heading "International Convention" it should be made clear that the application must be filed in the foreign country within twelve months of *filing the application* in the home country, and that such application must be accompanied by a certified copy of the specification in the home country and a declared translation in the language of the foreign country. Among the disadvantages of a Provisional specification should be included the warning that no damages can be obtained for infringement between the date of filing the Provisional Specification and the acceptance of the complete specification.



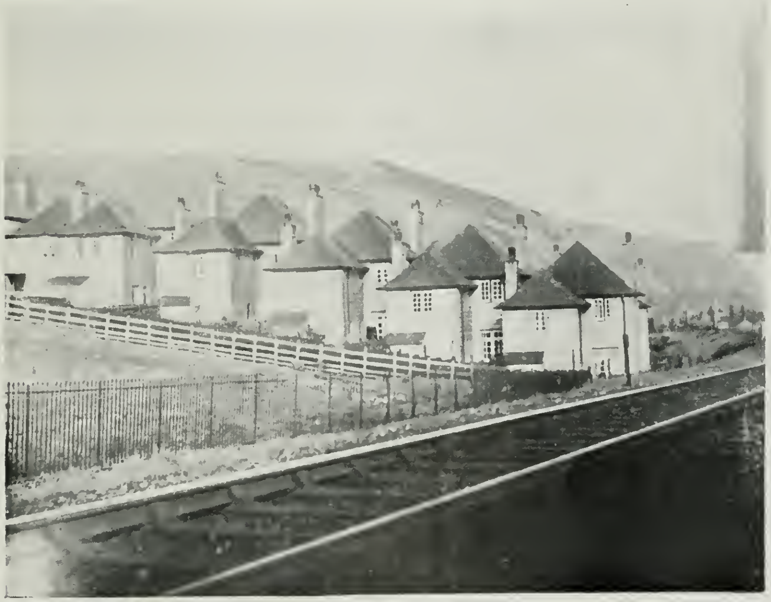
MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Elementary School Buildings.—Though the need for new schools is probably as great as ever, elementary school building has been practically stopped in all parts of the country. It is very likely that the stringency of the money markets will compel our local authorities to erect simpler and cheaper buildings after the war. Efforts are bound to be made to get the Local Government Board to relax some of their requirements with regard to schools, and the local authorities will have to amend their by-laws so as to allow new, but less costly, methods of building.

Architects have already had to devise cheaper schemes to meet special cases, and it is probable that the use of reinforced concrete, which has been already used in several mining districts for schools, will find a more general application. The schools erected of reinforced concrete appear to meet all necessary requirements, are permanent and sanitary, and if not very ornate, need be, by no means, unsightly.—*The Surveyor and Municipal and County Engineer.*

Cottages for the Employees of the G.W.R.—Below we give an illustration of some cottages which the Great Western Railway have erected for their employees at Goodwick. The cottages are of concrete, and so far about forty have been built.



South African Railway Construction.—The low-level permanent bridge over the Orange River at Upington, which was constructed in connection with the linking up of the railway systems of the Union and the Protectorate of South-West Africa, is said to be the longest railway bridge in South Africa. It is 3,000 ft. long, and consists of 102 spans, varying in length from 25 to 40 ft. The piers are of concrete founded on solid rock, and the superstructure is of rolled steel beams. The bridge was completed in four and a half months.

America's Dreadnought Yards.—The decision of the United States naval authorities to make the dockyard at Mare Island, California, capable of building large armoured vessels was not unexpected on this side of the Atlantic, for the establishment is, or soon will be, very conveniently situated, so far at any rate as dry dock accommodation is concerned. In the yard itself there is a reinforced concrete dock with a width at its entrance of 102 ft., and a depth on the sill at high water of ordinary spring tides of 31½ ft. At Hunter's Point there is another with a width of 144 ft. and a depth on the sill of 34½ ft., and adjoining it is a stone dock with an entrance 103½ ft. wide and a depth on the sill of 30 ft. The overall length of the shortest of the three is 750 ft., and that of the longest 1,050 ft. Several battleships belonging to the pre-Dreadnought period are products of the Pacific Coast, including the *Nebraska*, the *Ohio*, the *Wisconsin*, and the *Oregon*. With Mare Island brought up to date, the United States will have half a dozen yards fit to undertake the construction of Dreadnoughts.

A New Coal Dock for the Cincinnati, Hamilton and Dayton, at Toledo.—The following particulars are taken from the *Railway Gazette* :—With the opening of navigation on the Great Lakes this spring the Cincinnati, Hamilton and Dayton Railroad placed in operation at Toledo a modern coal-handling plant, dock and yard to provide adequate facilities for a steadily increasing coal traffic. Work on this project was not started until December, 1914. The new equipment is situated on the Maumee River, at Rossford. The new dock is placed at the harbour line, which is a change in the old arrangement in which the dock was 25 ft. shoreward. This change enables the large freighters plying on the lakes to tie up directly at the dock and load their cargoes more quickly. The terminal is laid out with a yard having a capacity of 236 cars, adjacent to the unloading machine, and in which 140 loaded and 96 empty cars can be handled. To the south of the dock is a classification yard with a capacity of 3,000 cars, affording ample space for assembling shipments.

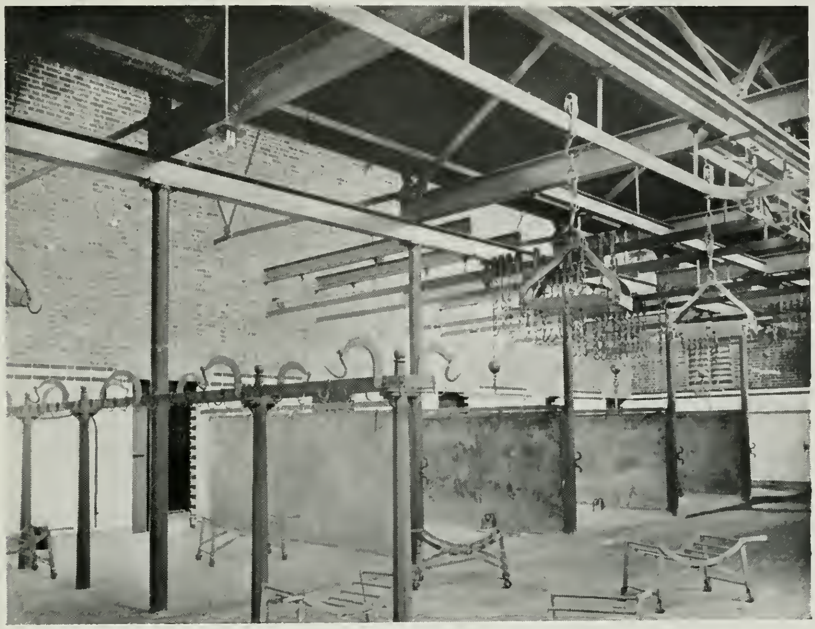
The plans as prepared called for the construction of 802 ft. of concrete dock, the necessary foundations for the machine, the entire reconstruction of the load and empty yards and the fabrication and erection of a new mechanical car dumper with the necessary approach and run-off trestles. This type of dock was placed on both sides of the machine foundation. The dock immediately in front of the machine is of the same general construction, except that the batter piles were omitted, and the dock was made a part of the machine foundation, this foundation being of pile construction, capped with reinforced concrete slabs to which the dock is anchored.

The piles in front of the old dock were driven by floating equipment, using steam hammers, while those behind the old dock were driven by land drivers. The piles were driven to refusal to a bed of hard pan and small granite boulders, approximately 31 ft. below the lake level. The cut-off for the dock was made at a point 18 in. below mean lake level. The operation of the floating equipment for driving piles and sheet piling was made possible during extremely cold weather by using an ice tug to keep the river ice broken and clear of the site of the work.

The construction of the machine foundation was undertaken first, and upon completion of the driving of the piles and sheet piles for this portion of the work, the fill between the old and new docks was placed. The driving of the piles for the dock on both sides of the machine was then started, and as the pile driving was completed and the sheet piling placed, the new work was connected with the old dock by means of temporary ties and the fill placed to the elevation of the bottom of concrete.

With the exception of the sand, all the materials used in the concrete work were brought to the site by rail. The sand was unloaded from boats at the dock site. The mixing plant was located about 1,000 ft. south of the machine, where the storage bins were provided and a heating plant for heating all material was installed. A boiler plant was also installed at the site of the machine foundation. The concrete was transferred from the mixing plant to the site of the work in drop-bottom buckets on flat cars, by means of narrow-gauge equipment. The concrete was placed continuously and without reference to the weather conditions. This was made possible by having the materials properly heated, and by keeping it warm after it was in place by means of the steam plant located at the machine foundation. Some of the concrete was placed with temperatures as low as 12° Fahr. below zero with no bad effects.

Reinforced Concrete Divisions in Slaughter-houses.—Some new public slaughter-houses have just been completed at Weston-super-Mare, and the main slaughter-hall is divided up into five parts by reinforced concrete divisions 6 ft. high. These divisions are shown in the accompanying illustration.



By Courtesy of the Surveyor and County and Municipal Engineer.

VIEW OF PORTION OF MAIN SLAUGHTER-HOUSE, WESTON-SUPER-MARE ABATTOIR, SHOWING REINFORCED CONCRETE DIVISIONS.

Cement Joints for Cast-iron Pipes.—Suggested Specification.—A committee of the American Gas Institute, which is at work on a study for cast-iron pipes, does not hesitate to recommend the cement joint in standard A.G.I. bells for small mains. The following specification embodies what the committee believes to be the best practice for cement joints :—

1. The efficiency of a cement joint depends on filling the clean joint with the maximum quantity of the proper quality of cement properly mixed.

2. In the A.G.I. standard depth bells cement joints should only be made up to and including 8-in. mains.

3. In 10-in. and over cement joints should preferably be made in deeper bells, the depth of which should be not less than that given in the following table :—

Inches.	Inches.
10—5	20—6¾
12—5½	24—7½
16—6¼	30—8½

4. Four, 6, 8, and 10-in. mains may be laid on the ditch bottom; 12-in. and over on blocking.

5. The spigots and bells must be clean and free from all loose material. Dirt and scale must be removed with wire brushes and scrapers. Tar or any substance of an oily nature may be removed with gasoline, but the pipe must be subsequently scrubbed with soap and water and rinsed thoroughly with clean water. Clean bare iron is absolutely necessary.

6. The ditch must be levelled to a true bottom and the bell holes dug. The pipe

must be entered, pushed home, and lined up without entering any packing whatever in the joint, thus departing from the old practice in small mains of using the back-packing to lift and enter the spigot into the bell and then driving up the back-packing to space the joint. With a properly bottomed ditch the joints will be very nearly spaced when the pipes are entered and lined up.

7. In 4-in., 6-in., 8-in., and 10-in. mains the joints must be spaced with wedges.

8. Tap in lightly two of the wedges about at the two lower thirds of the circumference of the pipe and the third wedge at the top. Sliding the forefingers around the joint is a simple and accurate method of determining if the joint is properly spaced. Sufficient wedges should be provided to allow laying as many pipes as desired before joint making.

9. Cover and tamp the pipe firmly into place between the bell holes. The tamped earth covering has two important functions—1. It holds the pipe firmly in place for the joint making. 2. It maintains the pipe at a much more uniform temperature during the progress of joint making and subsequently than would be possible if exposed to the atmosphere.

10. Use untarred jute packing dry and free from oil in the bales.

11. The back packing must be wet with clean water and thoroughly wrung out by twisting into a tight rope. This wet rope of packing must have a uniform diameter of from 7-16ths in. to ½ in. Do not grout the packing. This rope of packing should be of such length as to reach once around the spigot and lap 1 in.

12. Remove the wedges and enter the packing. If the spigot has a bead, use the yarning iron, driving the yarn into the wedge-shape recess formed by the bead on the spigot and the fillet on the back of the bell, as shown. Use a 4-lb. caulking hammer for all cement joint work. If the spigot is cut, use the yarning iron, which will compress the yarn as shown.

13. The cement should be a high-class medium setting American Portland cement, and must be in perfect condition and must all be passed through a No. 50 screen before mixing. Mix thoroughly by hand to a consistency of a stiff putty in such quantity that all will be used within fifteen minutes after mixing. Discard any mixed longer than this time. Mix in the shade.

14. With a small trowel fill the joint with cement flush with the face, then use a ½-in. cotton rope slightly longer than the circumference of the pipe, and drive in the cement with the caulking tool. Withdraw the rope and fill the joint flush with the face with cement. Wet and twist a piece of yarn that will be of uniform diameter of from 9-16ths to ⅝-in. when twisted tightly. Drive this yarn into the bell with wide-face caulking tool.

15. The making of the joint must proceed continuously, there being no lapse of time between the successive operations.

16. Point the face of the joint with cement, so that it is smooth, and flush with the face of the bell.

17. Do not make joints until the pipe has assumed, approximately, the temperature of the ground. If the sun shines in the ditch shield the pipe exposed in the bell holes from the direct rays of the sun. This becomes increasingly important as the size of the pipe increases.

18. Test the joints with soap and water under gas pressure. If the mains are intended to carry any higher than the usual low gas pressures, test them with air pressure and soapsuds at twice the pressure that the system is laid to carry. When testing with air at high-pressures, the test should not be applied until the joints have been made twenty-four hours or longer, and the greatest care must be used to avoid temperature changes in the pipe while waiting for the test.

19. The above method should be followed in the 4-in., 6-in., 8-in., and 10-in. mains. For mains 12 in. and over (mains 10 in. and over must have a special depth bells for cement joints) the same procedure as for mains 10 in. and under should be followed, with the following exceptions and additions.

20. After bottoming the ditch to a true line wood blocks are set in front of and behind each bell and carefully and solidly embedded, so that the top surface is the true plane of the bottom of the pipe. After laying the pipe and entering the joints are spaced by wooden wedges on the blocking.

21. With bells 6 in. and over in depth, after driving the cement in with the cotton rope and withdrawing the rope, the joint must again be filled with cement and again driven in with the rope, then filled again with cement and the front packing entered.

22. For mains 20 in. and over the rope of back packing must be from 9-16ths in. to ⅝ in. in diameter and the front packing from ⅝ in. to ¾ in. in diameter.

23. Increasing care must be used to maintain uniform temperature of the pipe as the size increases. Especial precautions must be taken to assure that there is practically no difference in temperatures between the top and bottom of the large pipe.

It is pointed out that one important advantage of the cement joint is that a main laid with this joint is practically a non-conductor. Data collected from electrolytic surveys indicate a large immunity in gas-made systems laid with cement joints.—*Gas World.*

Bahia Blanca, Argentine.—The harbour works which the Buenos Aires and Pacific Railway Company has had under construction since 1904 at Galvan Port, near the head of Bahia Blanca Harbour, have made progress during the year. Thirteen out of the sixteen ship berths included in the scheme at present in hand are already in use, and work is in progress on the remaining three berths on the north side of the port. The quay walls are of the concrete cylinder type, each cylinder having three wells. The depth of water alongside the quays varies from 21 ft. to 30 ft. at L.W.O.S.T. Further extensions on the south side of the harbour, including coal storage and handling plant, as well as two additional ship berths, are in contemplation.

At Puerto Belgrano, lower down the estuary of Bahia Blanca, the Argentine Government is engaged on extensions at its naval port and dockyard, which has been in course of construction for over fifteen years.

Valparaiso.—Good progress has been made with the construction of the Valparaiso harbour works, which are being carried out for the Government by S. Pearson and Son, Limited. In July, 1915, the first two sections of the sub-structure of the new breakwater had been completed. The construction adopted is rock rubble with pell-mell concrete blocks. The dredging and foundations for the Fiscal mole have been completed, and block setting is in progress. Work is also in hand at the Coal mole, which is a concrete cylinder structure, and dredging has been carried out at the Aduana mole.

Alexandria.—The construction of the new eastern harbour at Alexandria by the municipality of the town is being proceeded with rapidity. About two-thirds of the under-water work of the Kaid Bey breakwater have been finished, and it is hoped that this portion of the work will be completed in March next. The Kaid Bey arm is the first of two breakwaters which are to be constructed to form a sheltered area of about 600 acres in the eastern bay facing the Abbas II. Promenade. The work will be about 547 yards long, in an average depth of water of 26 ft. The construction adopted is a stone rubble sub-structure with 40-ton concrete blocks laid pell-mell on the surface and a coursed concrete block and masonry super-structure. The contract for the second arm on the Silsileh side of the bay has not yet been let. The proposed width of entrance between the piers is 383 yards. It should be pointed out that the new municipal harbour on the eastern side of the town is quite distinct from the more important western port or Government harbour. In days before the Christian era, the eastern port, or Magnus Portus, was the great naval base and commercial harbour of Egypt.

A Reinforced Concrete Road.—A somewhat remarkable reinforced concrete road is reported upon by the United States Department of Agriculture, this road having been carefully examined after having been in use—with a fairly heavy traffic—for over a year. The road, which is 4½ miles long, is single course, 18 ft. wide, 8 in. thick at the centre, and 6 in. thick at the sides. The foundation is an old macadam road and the maximum grade 5·8 per cent. The features of its construction were (1) thorough rolling of the sub-grade; (2) adequate provision for drainage; (3) minimum time for mixing each batch of concrete; (4) careful grading of sand; (5) accurate measurement of concrete materials in boxes; and (6) the use of wire-mesh reinforcement. The cost was £3,270 per mile. After being in use for a year only one small crack was found, and this was easily and cheaply filled in. As a comparison of price, it may be mentioned that a report on another rural road was issued at the same time. This was of brick on a concrete foundation and cost £5,687 per mile.

Irrigation of Fruit and Farm Lands, N.Z.—In connection with a scheme for the irrigation of land fruit growing near Cromwell, Central Otago, New Zealand, a number of works will be undertaken, and amongst them is the construction of a Power House entirely in reinforced concrete.

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Every description of PILE DRIVING PLANTS, and both our types of STEEL SHEET PILING are available for SALE OR HIRE.

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DOCK HOUSE, *Billiter Street*, LONDON, E.C.

SOME PROPOSED WORKS FOR 1916.

Retaining Wall.—Plans have been prepared and contracts will shortly be advertised for a new concrete retaining wall on the Brighton main road, to replace one which has collapsed owing to the extraordinary traffic on the road.

Bridges.—Two reinforced concrete bridges will be constructed at Lynn Burn and Byers Hall respectively, and a rolled steel joist and concrete road bridge at Low House Mill.

Philippine Islands.—The British Consul at Manila has forwarded a copy of a specification for the erection of a new central sugar mill at Isabela-Binalbagan. The contract includes the erection of buildings, warehouses, a wharf, etc. The specification may be consulted at the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, E.C.

Colombia.—The "Junta Central de Higiene" has presented a Note to the Government recommending various sanitary measures, amongst which are the installation of a complete sewerage system and the erection of extensive sea defence works. The opinion is expressed that the works should be entrusted to expert foreigners.

St. Pancras.—A tender by Messrs. W. King and Son, of £2,764, has been accepted by the Borough Council for the construction of concrete coal bunkers and lift well in connection with the extension of their electricity generating station.

Edinburgh.—Approval for the plans of the Portobello power station has been given by the Town Council.

Manchester.—During the month tenders have been invited by the Corporation for the erection of a power house at the Bradford Road Station for the Gas Committee.

Guildford.—Tenders have just been received by the Borough Surveyor for the erection of a retaining wall either in mass concrete or reinforced concrete on the Kahn system.

Thrussington.—The Leicestershire County Council has accepted the tender of Messrs. W. Moss and Sons, Loughborough, of £435 for the rebuilding of two arches of Thrussington Bridge in reinforced concrete.

London.—Tenders for the concrete foundations and general building work in connection with the extension of the power house of the St. Pancras Borough Council have been called for.

Churwell.—The tender of Messrs. J. Predale and Son, of Birstall, amounting to £870 17s. 10d., has been accepted for the concreting work in connection with the erection of a warehouse, etc., at Millshaw Leather Works, Churwell.

Greece.—There has been a call for tenders in the Greek Government *Gazette* by the Harbour Board of Piræus for the construction of works in the port at an estimated cost of about £140,000.

Oystermouth.—The South Wales Sea Fisheries Committee have submitted a scheme to the Urban District Council for the construction of a new lay-up in reinforced concrete at Mumbles at a cost of £1,500, and to contribute one-fifth of the cost.

Buckie.—The Treasury have intimated their willingness to finance by loan and to grant a curtailed but complete scheme for the harbour extension works at a cost of £40,000.

Australia.—The municipality of Bendigo has decided to seek Government sanction for an underground sewerage system at an estimated cost of £100,000.

New Zealand.—The Napier Borough Council propose borrowing £36,500 for carrying out drainage works.

Business in China.—The Assistant British Commercial Attaché in China reports that there is a steady demand for special bars for reinforced concrete systems. Discussing the methods by which trade is to be worked up, he says the great secret is to get as close to the consumer as possible, and the ultimate consumer is nearly always Chinese. Travellers who are sent out from home are furnished with introductions by the office of H.M. Commercial Attaché, and placed in touch with interested firms, both foreign and Chinese.

District Surveyors.—Several vacancies have recently occurred owing to the death or retirement of district surveyors in London, but the London County Council are not making any permanent appointments until after the termination of the war. The Council has extended the appointments of the following:—Mr. F. Hammond, Hampstead District; Mr. H. Lovegrove, South Islington and Shoreditch; Mr. T. E. Mundy, Chelsea.

Pre-War Contracts.—A lengthy discussion took place at the annual meeting of the National Federation of Building Trades' Employers on the question of obtaining some redress through the Government for contractors who have been seriously hit by having to carry out contracts entered into before the war. The feeling was unanimous that the sudden outbreak of war entitled those who had contracts on hand to consideration, but there was a diversity of opinion as to how far it was expedient to ask the Government to intervene. The majority at first decided to request the Government to recoup contractors for losses incurred in regard to contracts entered into with them, and with public authorities, but subsequently it was resolved to leave it to the discretion of the Committee to make representations.

TRADE NOTICES.

Messrs. Vislok, Ltd., 3, St. Bride's House, Salisbury Square, E.C., are putting on the market a new small tool for engineers' use. This tool is an expansible double boring cutter, known as a "Gauge-All." The principle of the invention is the connection of two pieces of high-speed tool steel by a centre of special soft metal alloy. A V-shaped iron or brass clip is placed round the centre and lightly struck with a hammer, This compresses the metal alloy and expands the cutter. By regulating the hammer blows minutely, accurate expansion is obtained. It should be observed that the machine tool operator expands the "Gauge-All" cutter in use, so that frequent visits to the tool room and other delays are largely dispensed with.

It is claimed for "Gauge-All" that its use enables the last fraction of value to be extracted from extremely expensive and increasingly rare high-speed tool steel—a claim which is certainly justified by comparison of its performance with those of old-style finishing cutters.

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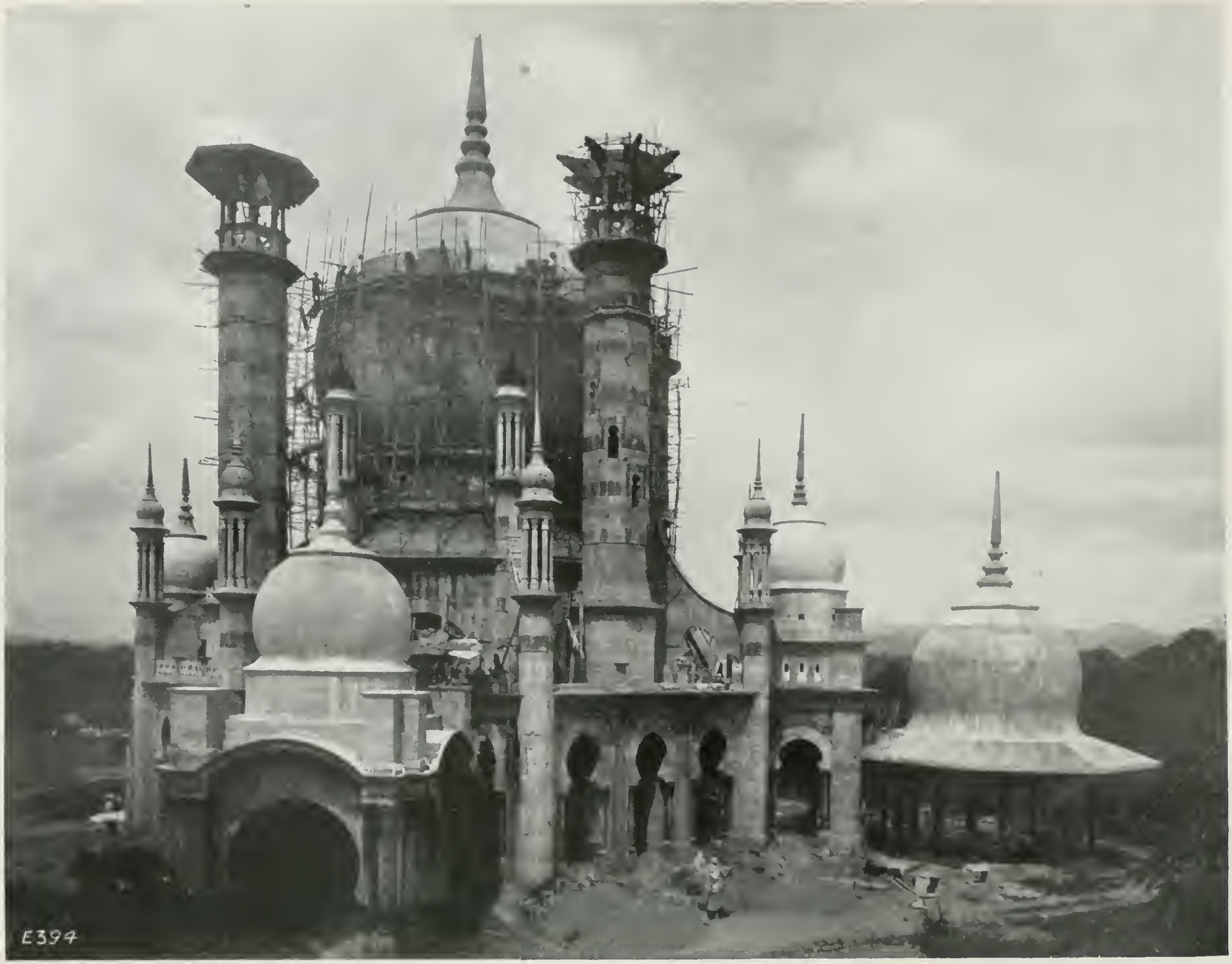


STATE MOSQUE AT KUALA KANGSAR, FEDERATED MALAY STATES, CONSTRUCTED IN REINFORCED CONCRETE.
(*See page* 203.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XI., No. 4. London, April, 1916.

EDITORIAL NOTES.

DANGEROUS STRUCTURES.

A very interesting paper on the subject of dangerous structures was read before the Concrete Institute on March 15th last by Mr. W. G. Perkins, District Surveyor for Holborn, and elsewhere in this issue we publish an extract from the paper, to which we draw our readers' attention. There is one point in particular which appealed to us in connection with this subject, and that is the amount of really useful information that can be gathered from a study of the failures which occur in buildings. Apart from his responsibility in the matter, the District Surveyor is fortunate in having excellent opportunities of dealing with structures which contain faulty construction, as he not only considers the possible effect of any such fault, but he also investigates the reason of the weakness and how it can be dealt with. In the course of these investigations he is bound to learn much that is of value in dealing with other structures in the future. We have always put forward the necessity of thoroughly investigating the causes of failures in reinforced concrete work, and the reason for our attitude is simply that much more can be learnt from failures than successes, and the same thing applies to failures in any type of construction. We shall possibly wake up in the future to the necessity of making a more serious study of the aspect of building work, as at the present time the causes of failure are only considered by the district surveyor, and probably the designer, if the latter be still available, and experience can only be obtained individually with such consequences that we all prefer to have nothing to do with the subject.

Mr. Perkins remarked on the quality of the work executed in "the good old times," which is so often held up by the uninitiated as the model of good construction and as being far superior to modern work. Those who have had to make alterations to such buildings, however, have had cause to think more highly of modern work, as the older types will not bear investigation. Bricks and mortar were generally defective, timber was often badly applied, and proper foundations apparently considered superfluous. The design and supervision of modern work is carried out on more scientific lines, and we do not think so much anxiety will be caused to district surveyors who are in practice one or two hundred years hence by the new buildings of to-day, as has been caused by structures which were erected by our predecessors.

An interesting example of the successful application of cement grout to a defective building where some timber posts had decayed was given, and this example is worthy of notice. The piers of the front external wall were yielding, and upon examination it was found that the piers consisted of timber cased with brickwork, and the timber had decayed. Sir Francis Fox, who acted for the owners, arranged to have the whole of the walls grouted with Portland cement. Numerous small holes were cut in the interior faces for the insertion of the nozzle of the grouting machine, and after well soaking and washing the interior of the wall with clean water under pressure from the machine, the grout was pumped in. After the process was completed the walls sounded and had the appearance of being solid, and the wooden posts were cut out of the piers and substituted by brickwork in cement.

The question of concrete made with coke breeze is one which has been discussed a great deal in the past, and widely divergent views are held as to the advisability of using this material. Mr. Perkins described it as a dangerous material, and stated that as it was specified in the London Building Acts as a fire-resisting material he had, much against his better knowledge, to pass it. There have no doubt been several cases of bad work in which coke breeze has been employed, but the fault lies in the bad quality of the breeze, and it is quite possible to get satisfactory results with this aggregate. In our Editorial Notes in the March issue of last year we made some observations on the same subject, and we would draw our readers' attention to these. Tests conducted on various types of concrete have shown that coke breeze aggregate is the most valuable fire resistant of all, and under these circumstances the material must not be condemned in a wholesale manner because architects and engineers allow an inferior quality to be used, but endeavours should be made to force merchants to supply a material of a higher standard, which could be used with safety, and the all-important point of fire resistance satisfactorily met. There are thousands of buildings in London in which this material has been extensively employed with satisfactory results; and where trouble has been caused the fault undoubtedly lies with those who were responsible for the supervision of the work.

The use of timber in forming foundations was rightly condemned by the author of the paper, who advocated the use of reinforced concrete, and every qualified architect and engineer will agree with his remarks on the subject. Mention was made of instances where the top flange of a steel joist was entirely cut away and chases 2 to 4 in. deep formed in 6 in. reinforced concrete floors at right angles to the reinforcement for the full breadth of the slabs for the purpose of running electric wires. Examples such as these are deplorable, and it is a pity to think that anyone responsible for work of any kind in a building should be so ignorant of the elementary principles of construction that they allow this sort of thing to be done. In the case of the reinforced concrete floor, if the work had not been noticed and failure had occurred, we should have heard the usual arguments against the advisability of using reinforced concrete construction put forward by just those people who are so ignorant of the subject that they would permit chases 4 in. deep to be cut in a 6 in. floor at right angles to the main steel!

Some remarks were made on the value of wind pressure, and although we do not belong to the "old school" we certainly consider that the figure of 30 lbs. per sq. ft. is excessive. We have previously expressed our views on this subject in the Editorial Notes, and need not reiterate them here.

CONCRETE WORK ON THE COPENHAGEN UNDERGROUND RAILWAY.

By GEORG BROCKNER.

Some interesting concrete work has been carried out on the Underground Railway at Copenhagen, of which some details and illustrations are given in the following article by our contributor.—ED.

THIS Underground Railway, now in course of construction, forms the connection between the new main Central Station and the East Station, and must be looked upon more as a connecting link within the railway system than as a town, and still less as a suburban, railway.

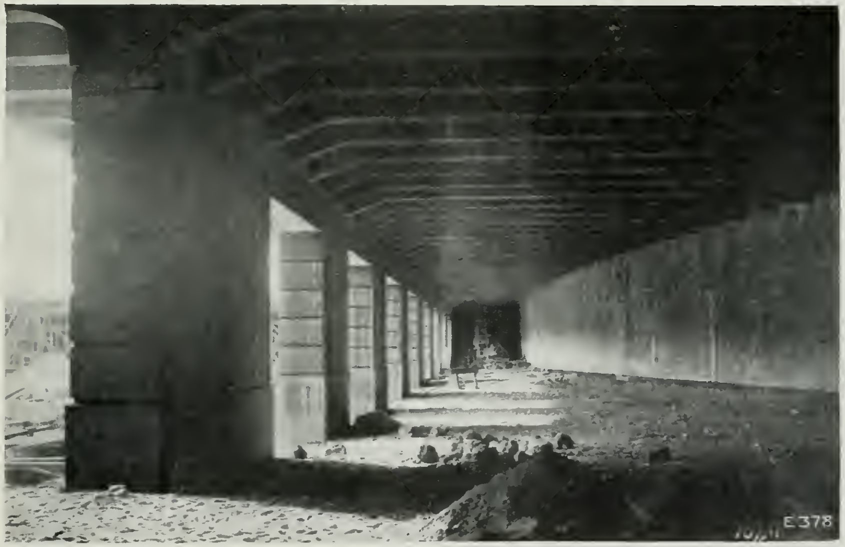


Fig. 1. Part of the line covered in north of main entrance to Central Station.
CONCRETE WORK ON THE COPENHAGEN UNDERGROUND RAILWAY.

Concrete work has also been used to a considerable extent in the construction of the new principal railway station, the interior of which, by the way, will—from an architectural point of view—vie with perhaps any European railway station. In the illustration, Fig. 1, part of the covered area is seen, with the railway lines, of the Central Station. To the north of the main building, the roofing or ceiling, which consists of reinforced concrete, supports a public thoroughfare. The two illustrations (Figs. 9 and 10) show the

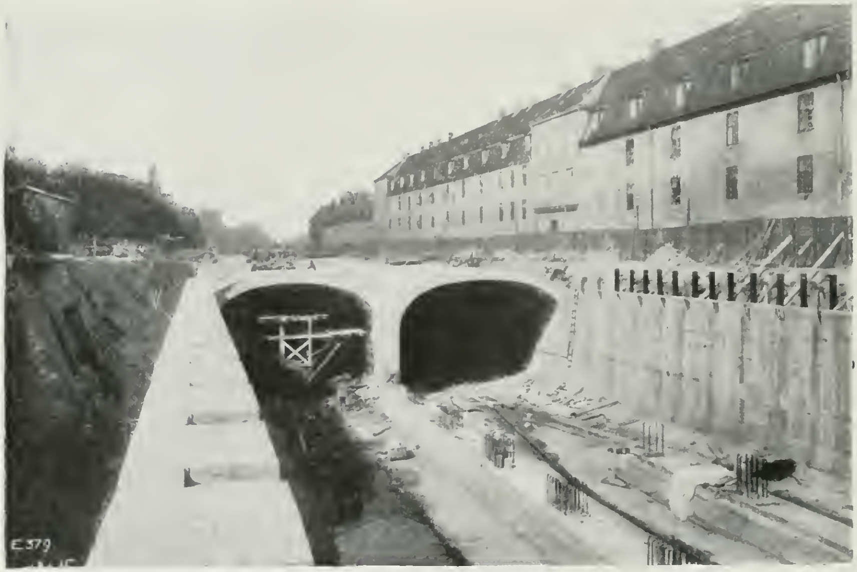


Fig 2. Northern end of the Frederiksborggade Underground Station.

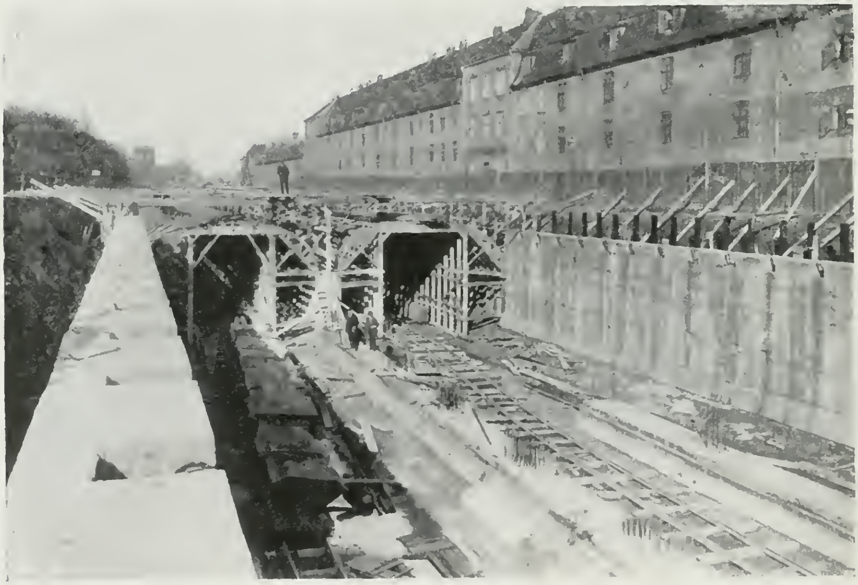


Fig. 3. Tunnel Scaffolding.
Concrete Work on the Copenhagen Underground Railway.

Vesterbrogade Viaduct, where the Underground Railway commences, in front of the main station. The bridge is made of reinforced concrete, the one illustration showing the reinforcement of the girders. The width of the bridge at the top is 65 m., the area covers 5,500 square metres, and the cost is 507,000 kr., including the parallel streets. The concrete is in the proportion

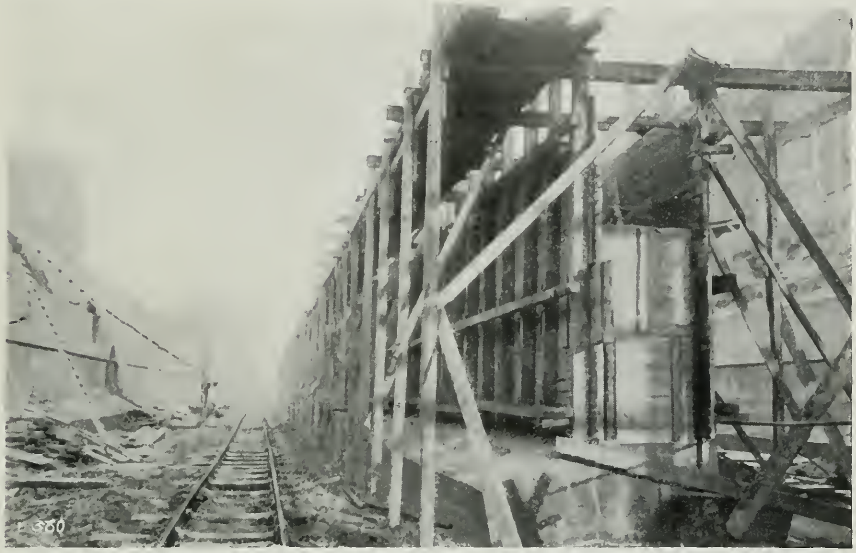


Fig. 4. Scaffolding for the Central Wall.

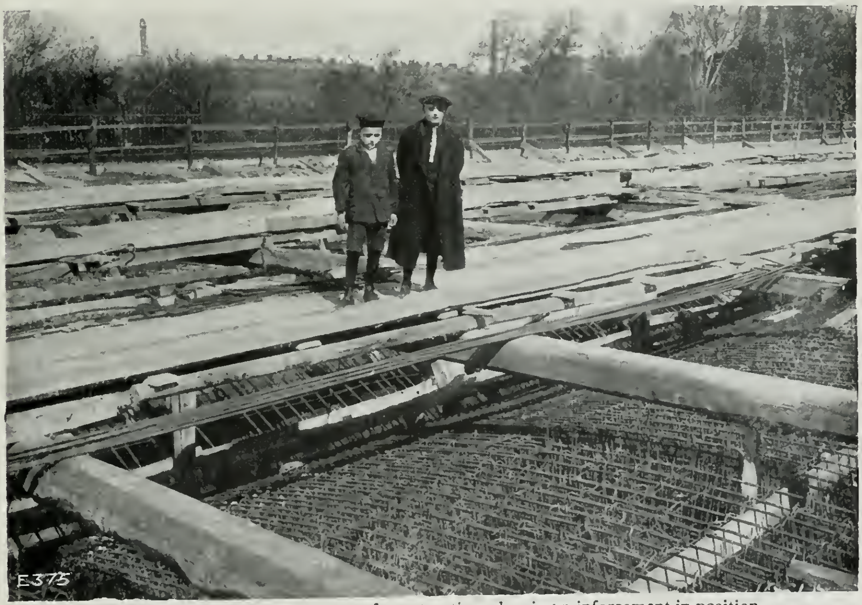


Fig. 5 Tunnel Arches in course of construction, showing reinforcement in position.
Concrete Work on the Copenhagen Underground Railway.

of 1 : 3 : 4, and the permissible load on the concrete and reinforcement is respectively 40 and 1,000 kilograms per square centimetre. In the main girders in Vesterbrogade lattice steel has been used. The depth of the beams is comparatively small, only about 0·9 m. to a width of span up to 15 m. All the visible concrete surfaces have been cast against plaster-covered boarding, whereby any subsequent polishing or finishing work can be dispensed with. In the pavements of the viaduct there are canals for cables and small pipes, whilst the larger gas and water pipes are carried in a tunnel underneath the railway lines. This tunnel has an inside breadth of 5·2 m. clear and a free height of 2·5 m. It is made of reinforced concrete, and there is a shaft at either end. As it is 3·3 m. below ordinary water level, it is insulated.

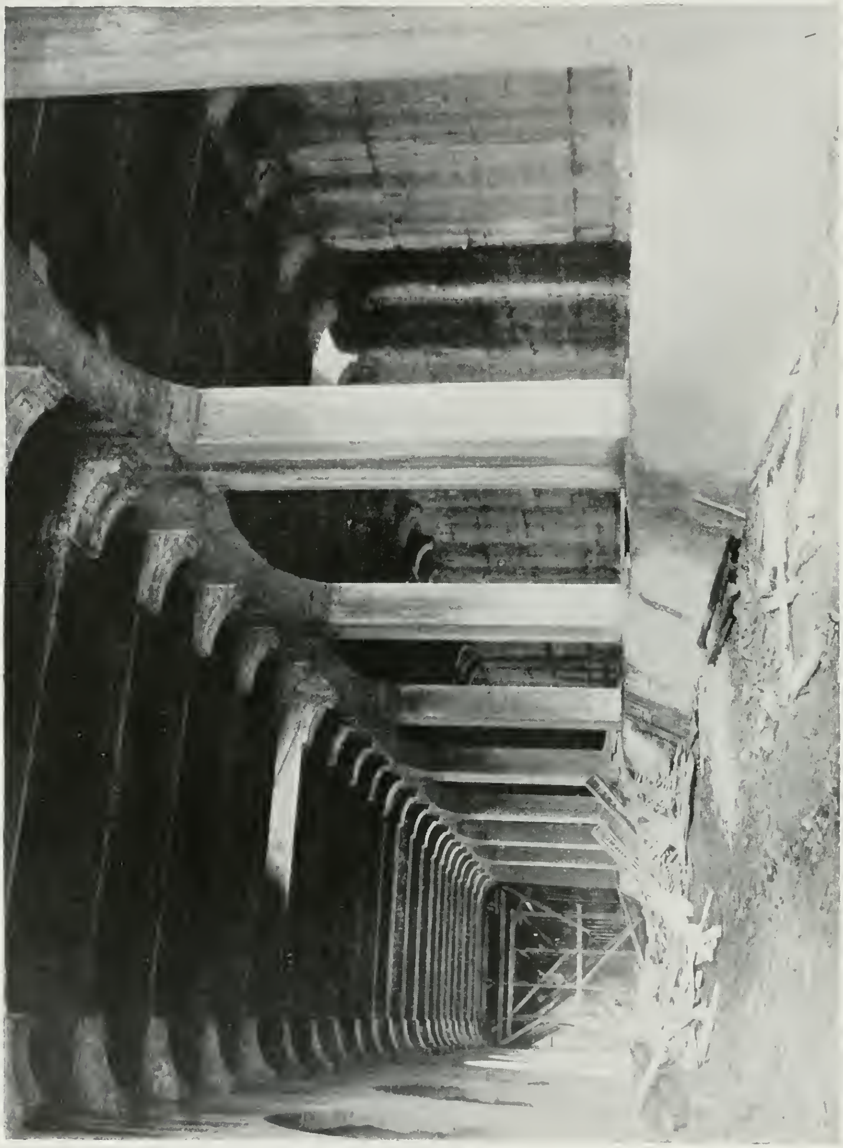


Fig. 6. Frederiksborggade Underground Station.
CONCRETE WORK ON THE COPENHAGEN UNDERGROUND RAILWAY.

The roadway of the Vesterbrogade Viaduct was so arranged that rails for trams could be placed anywhere, there being a layer of not less than 16 c.m. filling-up concrete above all the supporting constructions, which, with an asphalt layer of 5 c.m. thickness, affords sufficient accommodation for the laying of rails. So as not to interfere too much with the traffic, which is very important in this thoroughfare, the work was carried on in two sections, the southern half, nearest the station, being completed first, the traffic in the mean-

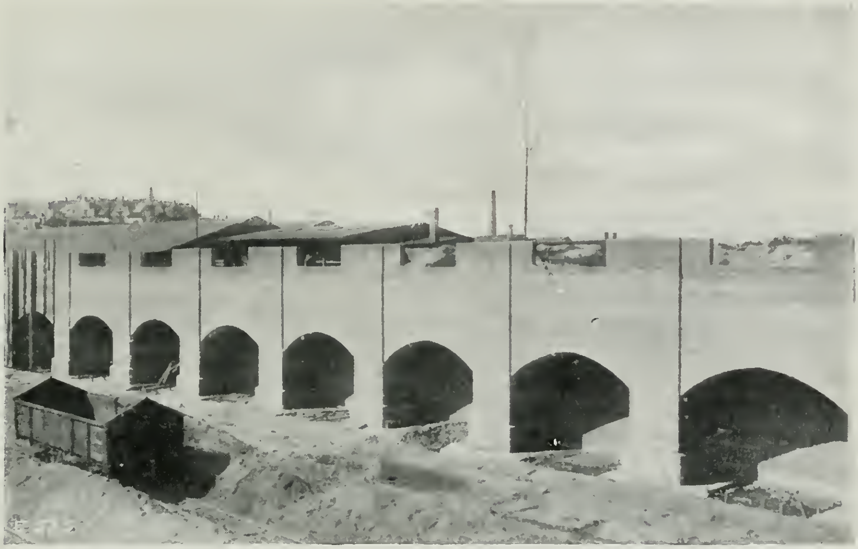


Fig. 7 The surrounding wall between Vesterbrogade and Aborne Park in course of construction.

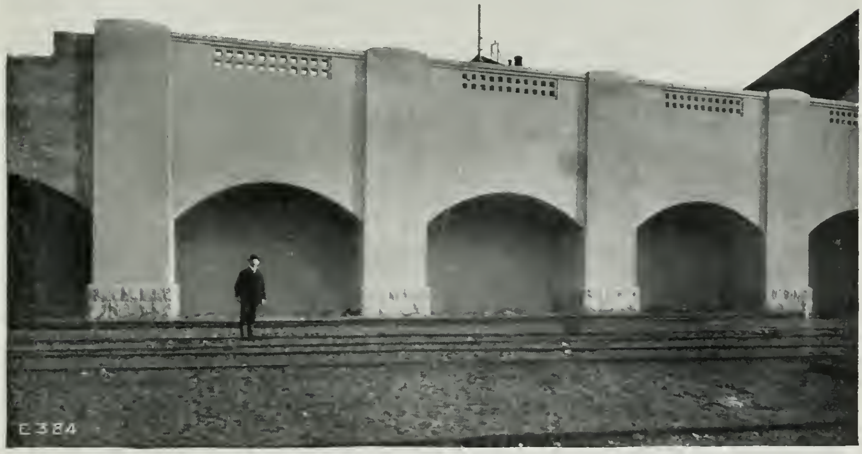


Fig. 8. The above wall completed.
Concrete Work on the Copenhagen Underground Railway.

time being carried across a temporary road, curving round the section in course of erection. On the spot which has since become the centre of the viaduct, there stood a famous historical monument, a tall obelisk, surrounded by allegorical figures. Several suggestions were made as to where this should be re-erected, but in the end it was decided that it should occupy its old place. The foundation of the column has been carried down to a firm basis underneath the railway lines.

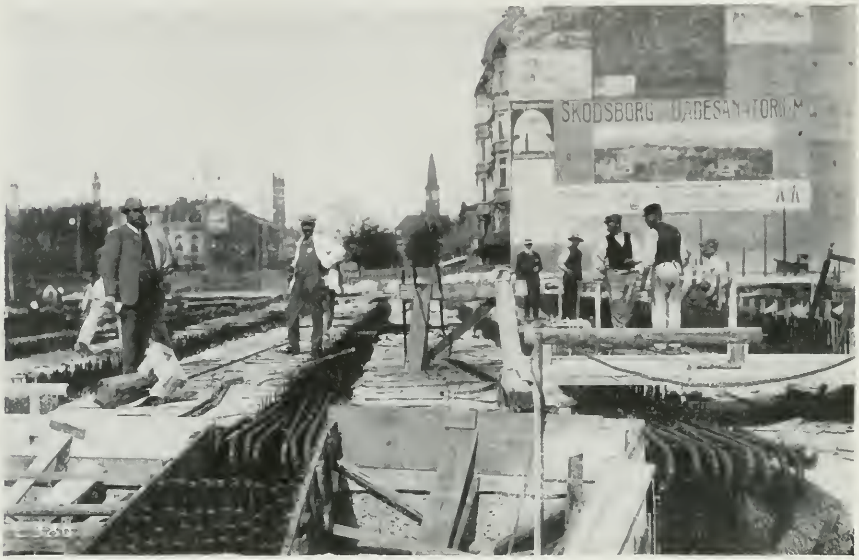


Fig. 9. Reinforcement in the Vesterbrogade Viaduct.

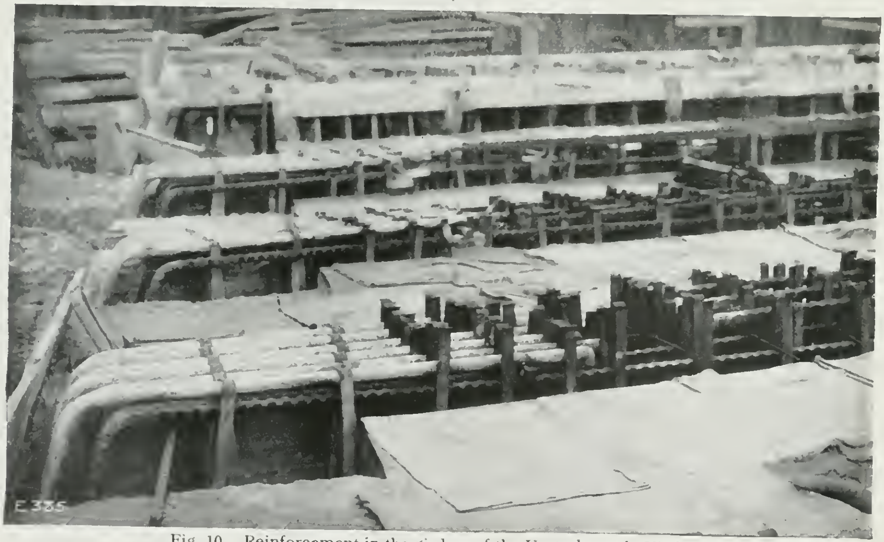


Fig. 10. Reinforcement in the girders of the Vesterbrogade Viaduct.
CONCRETE WORK ON THE COPENHAGEN UNDERGROUND RAILWAY.

The Österbrogade Viaduct, at the other end of the Underground Railway and in front of the East Station, is, like the one just referred to, built in two sections, so as not to disturb the traffic unduly. This viaduct is 60·6 m. broad and passes over six sets of rails. Besides the two end pillars there are five rows of pillars, eleven pillars in each row. The roadway is supported by Visintini girders; the reinforced concrete is a 1 : 3 : 4 mixture; the depth is about 0·7 m.; and the width of span of the Visinitini girders is about 12 m. The free height above the rails is 4·93 m. Here, again, all the visible concrete surfaces are cast against plaster-lined wooden moulds. Both viaducts

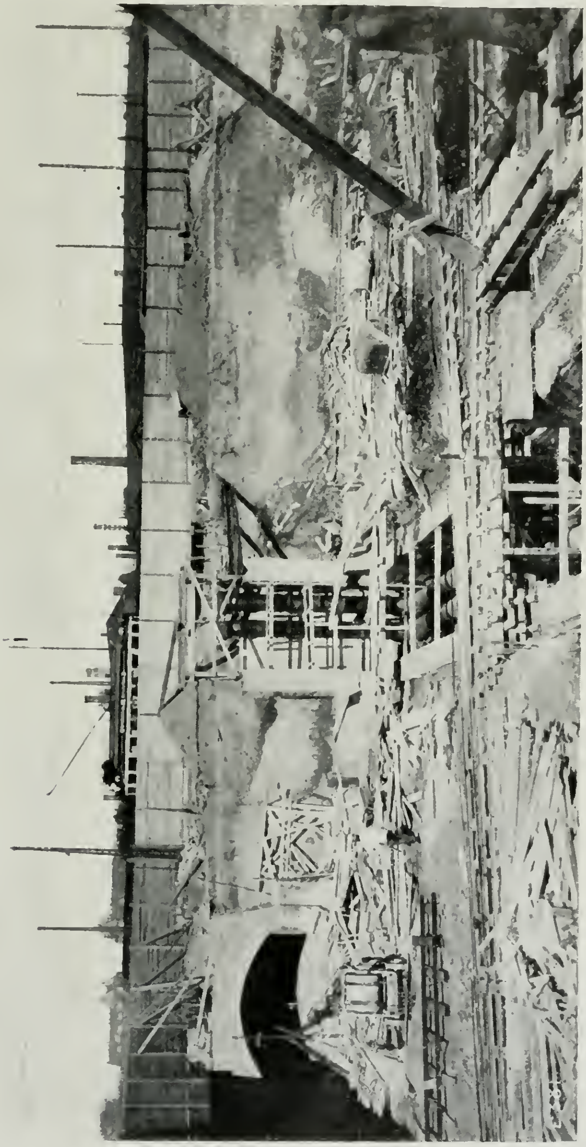


Fig. 11. Concrete tunnel for pipe lines below railway.

CONCRETE WORK ON THE COPENHAGEN UNDERGROUND RAILWAY.

are flanked with very handsome stone balustrades. As with the Vesterbrogade Viaduct, there are canals in the footways for carrying cables and smaller pipes across and there is a somewhat narrower reinforced tunnel under the lines for bigger gas and water pipes.

The Underground Railway proper—or, as it is generally called, the Boulevard railway, because it mostly follows the direction of the Boulevards, has been divided into five separate sectional contracts, the amounts of which, commencing from the East station, were 1,500,000 kr., 800,000 kr., 1,750,000 kr., 400,000 kr., and 450,000 kr. respectively. Some of these sections are completed, and the rest will probably be finished within the present year, although the war has caused some delay. On account of the line being a regular portion of the State Railway System, intended to connect the north and coast railways with the rest of the State Railway System, the sectional dimensions are much larger than is generally the case with underground railways. The Copenhagen underground has two tunnels of about 8·8 m. by 6·5 m. section, whilst that of the Berlin underground is only 6·3 m. by 4·0 m. altogether, and the one at Hamburg 6·8 m. by 4·0 m. In order to prevent cracks occuring through changes of temperature cross grooves have been placed 20 m. apart throughout the length of the tunnel. Owing to the great depth at which the tunnel has been constructed, a very careful insulation has been necessary. This has been accomplished by means of "callendrite"; the callendrite layer at bottom and sides is 5 mm., and at the top 2 mm., so that the tunnel is virtually cased in with this insulating material, which forms a coherent coating.

The underground station at Frederiksborggade is also built of concrete; the side walls are 2 m. thick and have some reinforcement at the bottom and back, but the bottom of the tunnel itself is somewhat more strongly reinforced. The station is covered with a flat roof, resting partly upon the side walls and partly upon the rows of reinforced concrete pillars. The roof is strongly dimensioned, having not only to sustain the street traffic but also to support a considerable layer of earth.

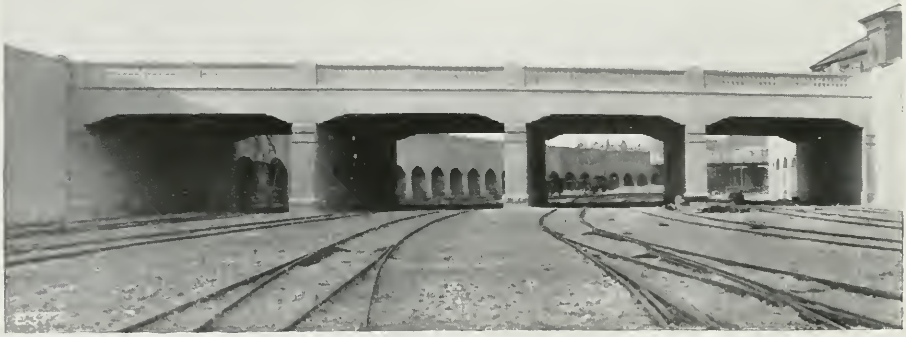


Fig. 12. The Gamle Kongaver Reinforced Concrete Viaduct.
Concrete Work on the Copenhagen Underground Railway.

RECENT BRITISH PATENTS RELATING TO CONCRETE.

We propose to present at intervals particulars of British Patents issued in connection with concrete and reinforced concrete. The last article appeared in our issue of January, 1916.—ED.

Ties for Concrete Reinforcement — *No.* 21,851/14. *W. J. Stewart, Elgin Street, Belfast, and J. Woolcock, of J. and W. Stewart, Caxton House, Westminster. Accepted October* 28/15.—The essential feature of ties for the reinforcement of pillars, piles, beams, and other structures in accordance with this invention is that the wire is bent so as to embrace once or twice the centre of three rods and to be looped round the other two which are angularly arranged, the free ends, *c*, being twisted and projecting inwards into the core.

Figs. 3-6 show two alternative forms of tie prior to assembling on the main reinforcement, and *Fig.* 2 shows them assembled and twisted in a column.

The ties can be conveniently made by bending them around three pegs of the same diameter as the main reinforcement and in the same relative positions. In the first form the wire is looped on to the centre peg, both ends being of equal length; the ends are then crossed close up to the centre stud and loops then formed with the wires at the other studs, the ends are then finally bent round the centre stud. A similar procedure is followed for the second form, but the ends are taken to the other studs without crossing at the first. The reinforcement may be stiffened by means of flat struts, *t*.

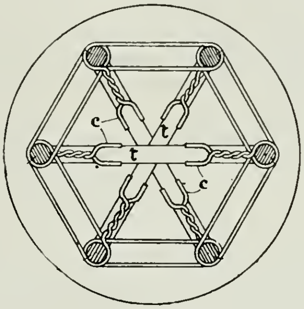


FIG. 2

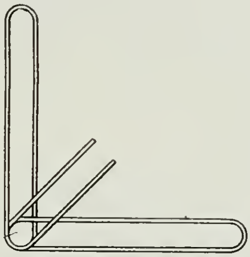


FIG. 3

FIG. 4

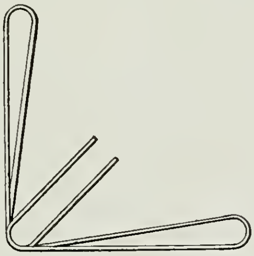


FIG. 5

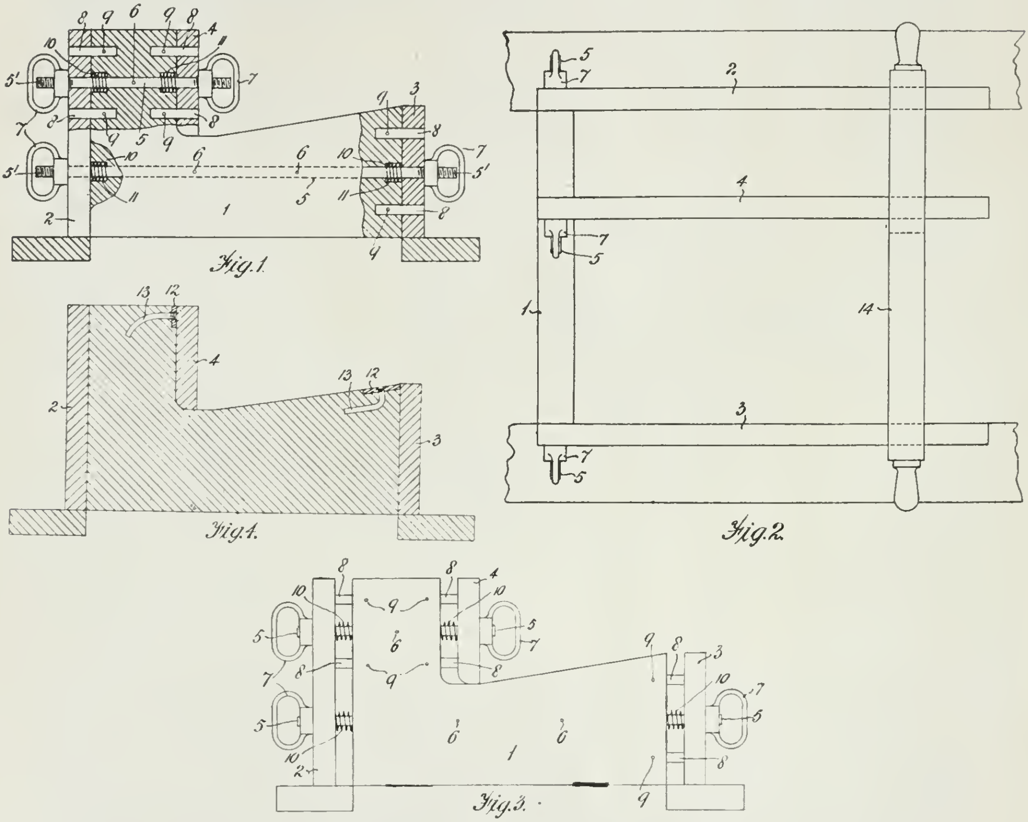
FIG. 6

TIES FOR CONCRETE REINFORCEMENT.

The twisting together of the ends of the ties serves to tension them and to fix them to the main reinforcement.

Concrete Pavement Kerbs and Gutter Channels. — *No.* 145/15. *William Calway,* 1, *South Road, Redlands, Bristol. Accepted December* 30/15.—The invention comprises an improved method and expanding mould for casting *in situ* concrete pavement kerbs and gutter channels. The mould has a stationary end plate, 1, shaped to the desired cross-section of kerb and gutter channel, and carries bolt-rods, 5, by means of which it is attached to vertical cheeks, 2, 3, 4. These cheeks are pressed into contact with the end plate against the pressure of helical springs, 10, by loop-nuts, 7, guide pins, 8, carried by the end plate engaging corresponding holes in the cheeks; when the loop-nuts are slackened the mould expands under the action of the springs in the manner shown in *Fig.* 3. One or more saddle-pieces, 14, *Fig.* 2, are employed to prevent the cheeks from opening out while the concrete is rammed.

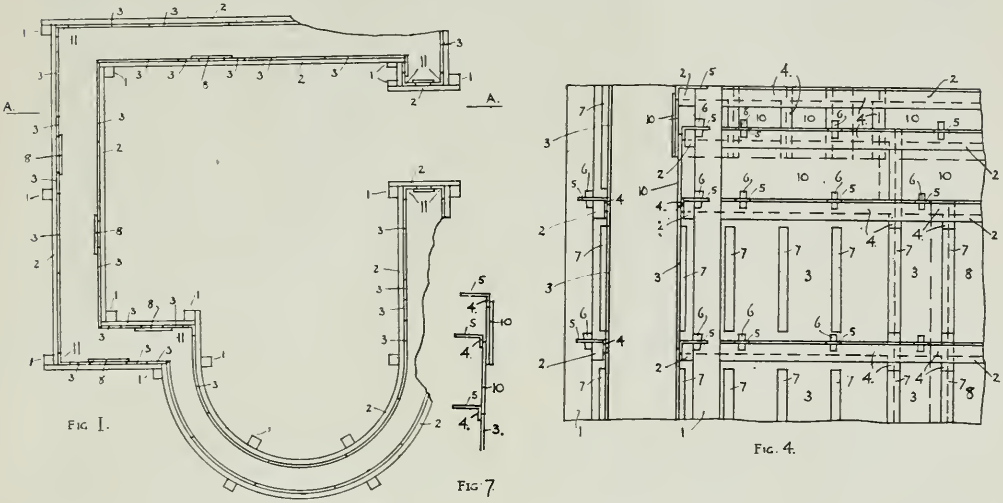
The method of using the mould is as follows: The mould is placed in a trench of the necessary dimensions and the opening is closed in any suitable manner for casting the first section. The mould is then filled with concrete and rammed, suitable facings, such as bars, 12, *Fig.* 4, with anchor rods, 13, being incorporated in the concrete. When the first section has set, the loop-nuts, 7, are slackened and the saddle-pieces, 14, are removed, thus allowing the mould to expand and to be withdrawn sufficiently far to cast the next section. This sequence is repeated until the required length has been cast. Boards are placed in the trench to facilitate the expansion of the cheek and the rearward displacement of the mould. The end plate and cheeks are preferably constructed of wood faced with sheet iron. Various forms of facings and rounded edges may be employed.



Concrete Pavement Kerbs and Gutter Channels.

Forms for Concrete Walls, etc.— *No.* 13,118/14. *H. Quilter, P.A.S.I.*, 13, *Percy Road, Hampton-on-Thames. Accepted December* 9/15.—This invention comprises an improved construction of mould of the type in which a series of plates are supported by hangers from a temporary metal or timber skeleton framework. According to the invention, metal strips to overlap the plate are attached on two adjacent edges of the latter, and one strip is provided with extensions which are bent at right angles to form hangers by which the plates are supported.

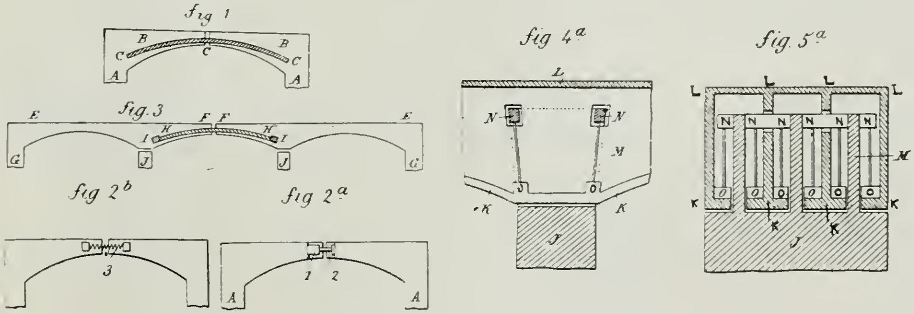
The plates, 3, which are hung from the framework composed of bars, 1 and 2, have attached to them at intervals parallel bars, 7, which stiffen them but allow them to be bent about lines parallel to the bars. The strips, 4, on two sides overlap the adjacent plates, and one of each pair has extensions, 5, which are slotted to receive wedges, 6, by means of which they are supported by the frame bars, 2. To allow for slight variations in the lengths of walls, extension plates, 8, are provided, which are similar to the plates, 3, with the exception that the strips and stiffening bars are on the inner side and their lower edges are slotted to pass over the projections, 5, of the plate below; these plates are similarly secured to the framework by means of wedges.



Moulds for Concrete Walls, etc.

Extension plates, 10, for the height of the wall have no stiffening bars, but are otherwise similar to the plates 3. Angle plates, 11, are employed for the angles of openings, piers, etc., and for the lower angles of beams; they are similar to the plates 3, but are bent to a right angle and have extensions, 5, on each of the strips for fixing horizontally or vertically.

Cantilever Bridges.—*No.* 351/15. *L. Pelnard-Considère, 8, rue Armand-Moisant, Paris. Accepted January* 10/16.—This invention has reference to bridges, comprising two cantilevers integral with their abutments, the earth pressures on which, combined with the loads on, and weights of, the cantilevers, tend to tip them towards each other. In accordance with the invention, the overturning moments are



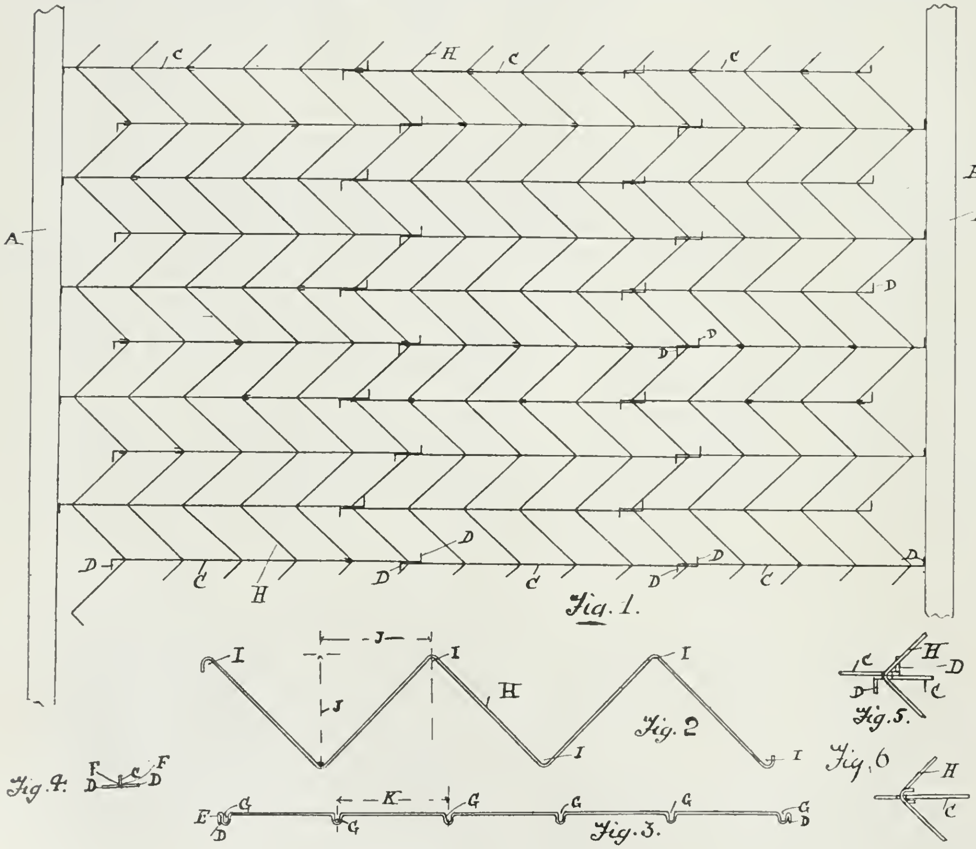
Cantilever Bridges.

neutralised by a thrust produced by an adjustable device such as an arch, springs, hydraulic press, or weighted levers, the arrangement in each case being such that the thrust is independent of small variations in the gap between the two ends of the cantilevers.

In *Fig.* 1 the cantilevers, *B*, carry arches, *C*, which do not carry the load transversely, but act as bent springs, and their form is independent of the superloads, the thrust of the arches being capable of adjustment; in *Fig.* 2*a* one or more hydraulic cylinders, 1, and rams, 2, are employed, the pressure being maintained constant by means of an accumulator; in *Fig.* 2*b*, springs, 3, are arranged between supports or beams carried by the cantilevers.

The application of the invention to three spans is shown in *Fig.* 3. The cantilevers, *E*, are integral with their abutments, *G*, but are so constructed as to be relatively movable with reference to the intermediate piers, *J*. Thrust arches, *H*, abut against transverse beams, *I*, which are integral with the cantilevers. Three methods of giving the requisite relative movement with respect to the intermediate piers are described. In one arrangement flexible rods, *N*, *O*, *Figs.* 4*a*, 5*a*, are connected at their upper ends to walls, *M*, projecting from the abutments, and at their lower ends to vertical members forming part of the cantilevers; in another arrangement a roller bearing is employed; while in the third the pier is hollow and allows a rocking movement upon its base of a heavy leg projecting vertically from the cantilever.

Reinforcement for Road Foundations.—*No.* 5,177/15. *Richard Ames,* 145, *Ditchling Road, Brighton, Sussex. Accepted November* 11/15.—For reinforcing con-



Reinforcement for Road Foundations.

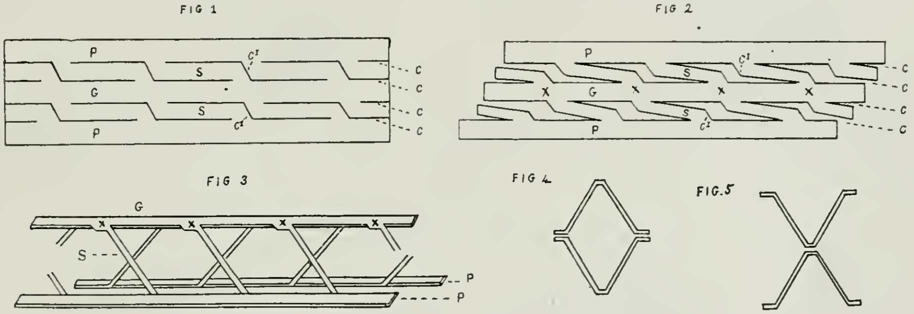
crete foundations for roads, a metal framework in accordance with this invention is formed of straight bars provided at intervals with cranked depressions for accommodating zig-zag transverse bars, the whole capable of being easily transported and laid without riveting, welding or binding.

The straight bars, *C*, which extend across the road from curb to curb, *A*, are in short lengths of about 5 or 6 ft., and preferably from $\frac{1}{4}$ to $\frac{3}{8}$ in. in diameter; they are formed with bent feet, *D*, and the cranked depressions, *G*, are spaced at intervals of about 12 in. apart. The zig-zag transverse bars, *H*, are preferably of slightly heavier section than the bars, *C*, and at the points of the bars, *H*, they rest in the same cranked depression of the bar, *C*, as shown in *Fig.* 6.

It is claimed as an advantage of the invention that in cases where it is necessary to cut through the foundation to obtain access to sewers, etc., the bars need not be cut through; it is only necessary to cut a number of short shallow trenches on each side of the main trench to release the cross bars, which can then be detached from the concrete.

Expanded Reinforcement for Concrete.—*No.* 11844/15. *A. Benham, "Benhilton," Westbury Road, New Malden, Surrey, and T. B. Smith, 88, Church Road, Hanwell, Middlesex. Accepted February* 10/16.—This invention comprises an improved form of expanded structure for reinforcing concrete made by slitting a sheet in a particular manner and then expanding to reticulated form, the main bars of the reinforcement coming into a triangular arrangement.

Each slit consists of two parallel portions, *C*, joined by a short inclined portion, C^1, the exterior portion, *P*, and the centre portion, *G*, of the sheet remaining integral. The centre portion, *G*, is then pressed out of the plane of the exterior portions, *Fig.* 2 showing the initial stage of the expansion, and *Fig.* 3 the final form.

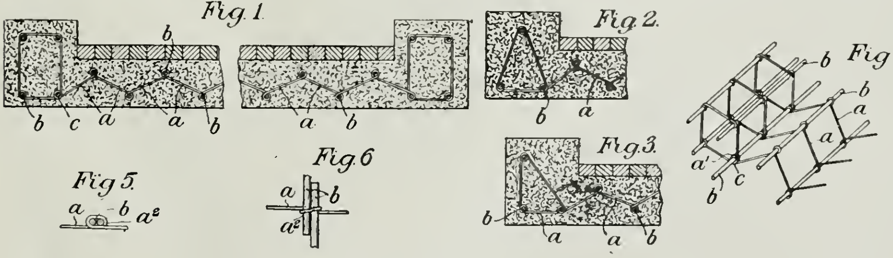


Expanded Reinforcement for Concrete.

The inclined portion, C^1, of the slits, which form a feature of the invention, cause strengthening portions, *X*, *Fig.* 3, to occur at the connection of the diagonals with the centre bar, *G*.

Figs. 4 and 5 show the arrangement of the reinforcement for round and square piles respectively.

Concrete Reinforcement.—*No.* 1422/15. *A. W. C. Schelff and T. S. Allden, Caxton House, Westminster. Accepted January* 27/16. The reinforcement, in accordance with this invention, which is particularly applicable to road and other founda-



Concrete Reinforcement.

tions, consists of a fabric arranged in zig-zag ridges and having the parts connected independently of the concrete, top and bottom reinforcement being provided by one layer of fabric.

Figs. 1 and 3 show three forms of the reinforcement employed in a roadway. The main reinforcement bars, *b*, which may be plain or of other approved section, pass through loops in the zig-zag bars, *a*. The bars, *a*, in the curbing preferably start at the bar, *c*, and are looped again over the bar, *b*, at this point, and then proceed in zig-zag manner, as shown in *Fig.* 4. At a joint in the main reinforcement a double loop, a^2, is provided, as shown in *Figs.* 5, 6.

In a modified arrangement three rows of main reinforcement bars are adopted, two sets of zig-zag looped bars being arranged between them.

The two sets of bars are intended to be transported separately and to be assembled on the site.

Metal Reinforcing Fabrics.—*No.* 10,384/15. *Moritz Kahn, Caxton House, Westminster. Accepted December* 20/15.—The metal reinforcing fabric made in

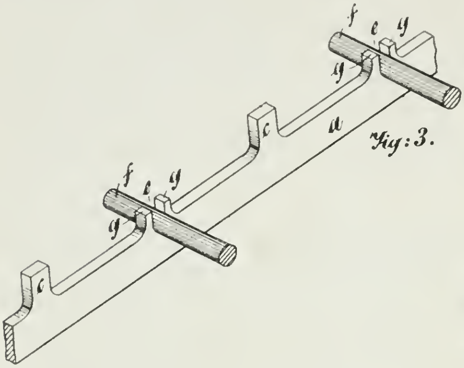


Fig: 3.

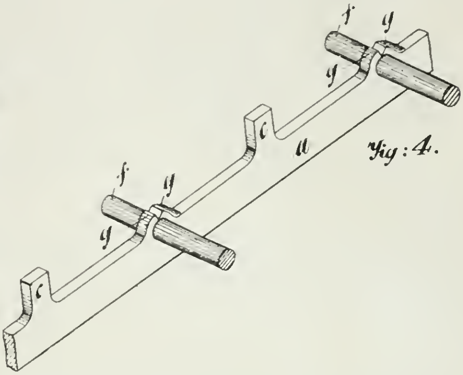


Fig: 4.

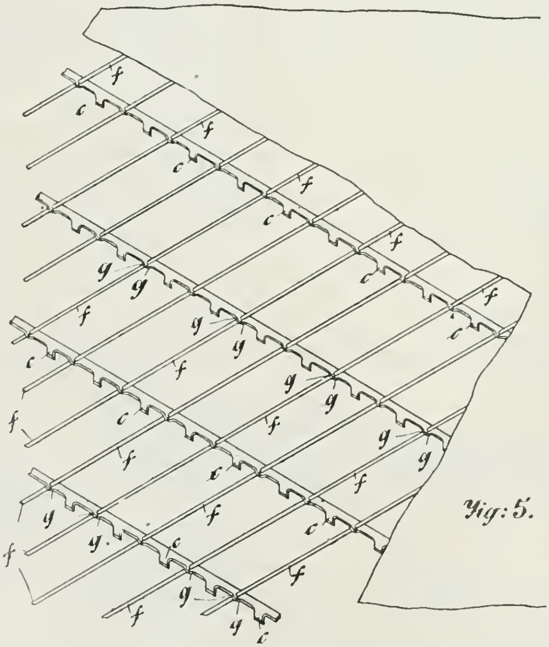


Fig: 5.

Metal Reinforcing Fabrics.

accordance with this invention is particularly suitable for fireproof ceilings and partitions, and comprises longitudinal bars which are of constant section throughout, these members being secured by transverse bars with gaps which are secured to the longitudinal bars by being bent over or otherwise deformed.

The transverse bars, *a*, have portions cut out so as to leave substantially equidistant projections, *c*, of small cross section and intermediate raised portions, *d*, which are punched to admit the plain longitudinal bars, *f*. The resulting jaws, *g*, are then closed down by a hammer or other appropriate means. The bars, *a*, should be so arranged that the projections, *c*, point towards the nearest surface of the concrete; in ceiling constructon, for instance, the projections point downwards and rest upon the shuttering, thus forming a spacing gauge for the depth of the reinforcement.

Reinforcing Bars with Integral Shear Members.—*No.* 7204/15. *H. H. Thompson,* 12, *Carteret Street, Queen Anne's Gate, S.W. Accepted February* 10/16. The reinforcing bar, in accordance with this invention, comprises a rail section, the web, *c*, of which is slotted at intervals throughout its length. The lower flange, *a*, has the necessary area required for the tension reinforcement, and the shear reinforcement is obtained by slitting the top flange, *b*, at the required intervals, and separating the necessary web portions, the top flange then being bent upwards, as shown. Additional shear members may be attached to the bar if required.

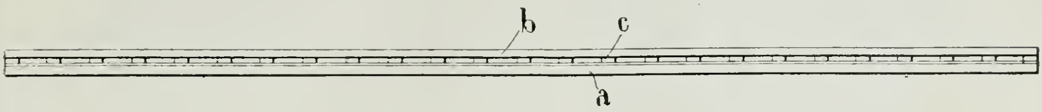


Fig. 1.

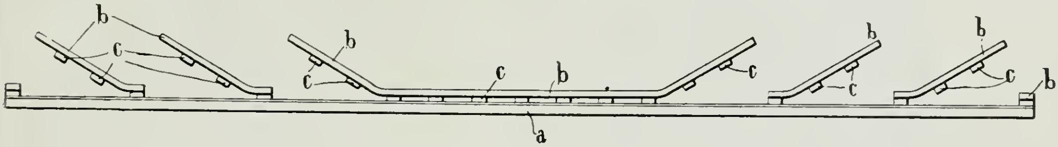


Fig. 3.

Reinforcing Bars with Integral Shear Members.

REINFORCED CONCRETE WAREHOUSE, MANCHESTER, for MESSRS. RALLI BROS.

By ERNEST G. SOUSTER, A.R.I.B.A.

The following is an interesting example of the application of reinforced concrete to warehouse construction.—ED.

This warehouse, which has been recently finished, is noticeable on account of the whole of the structural work in it being of reinforced concrete.

Its position, overlooking the river Irwell, and its size gave the architects a unique opportunity for expressing in the façade the character of this class of building, and the view of the exterior shows how well they have succeeded.

No extraneous materials have been introduced for effect, and, except for the curved pediments and the cornices, every line is but the outcome of the structural necessities of the building, and the whole forms a striking testimony to the capabilities of the use of reinforced concrete.

The external walls are left as they appeared when the timbering was removed, and with the exception of part of the entrance front and a brick party wall the structure is entirely of concrete and steel. By forming the walls of this material a great saving of space was effected, for a building of this height if of brick or stone construction would have needed very thick walls, and, moreover, the cost of such walls would have been very much higher. Throughout the building the external walls are 7 in. thick up to the cornice and 5 in. thick above that point, except where rustication is introduced, where the thickness is 11 in. The internal walls are still thinner, being only 4 in. thick around the staircases and lifts.

The above-stated thicknesses do not apply to the wall of basement which, by reference to section (*Fig.* 3), is seen to be greater, but this was necessitated by the need of a retaining wall to the River Irwell, upon the towpath of which the warehouse abuts and which, in times of flood, will put great pressure upon the building.

This wall was designed in conjunction with the heavy stancheon loads, which, of course, bring down an immense weight upon it and prevent any tendency towards movement. It may also be mentioned here that the use of the towpath shown on *Fig.* 3 was not interfered with during the progress of the works.

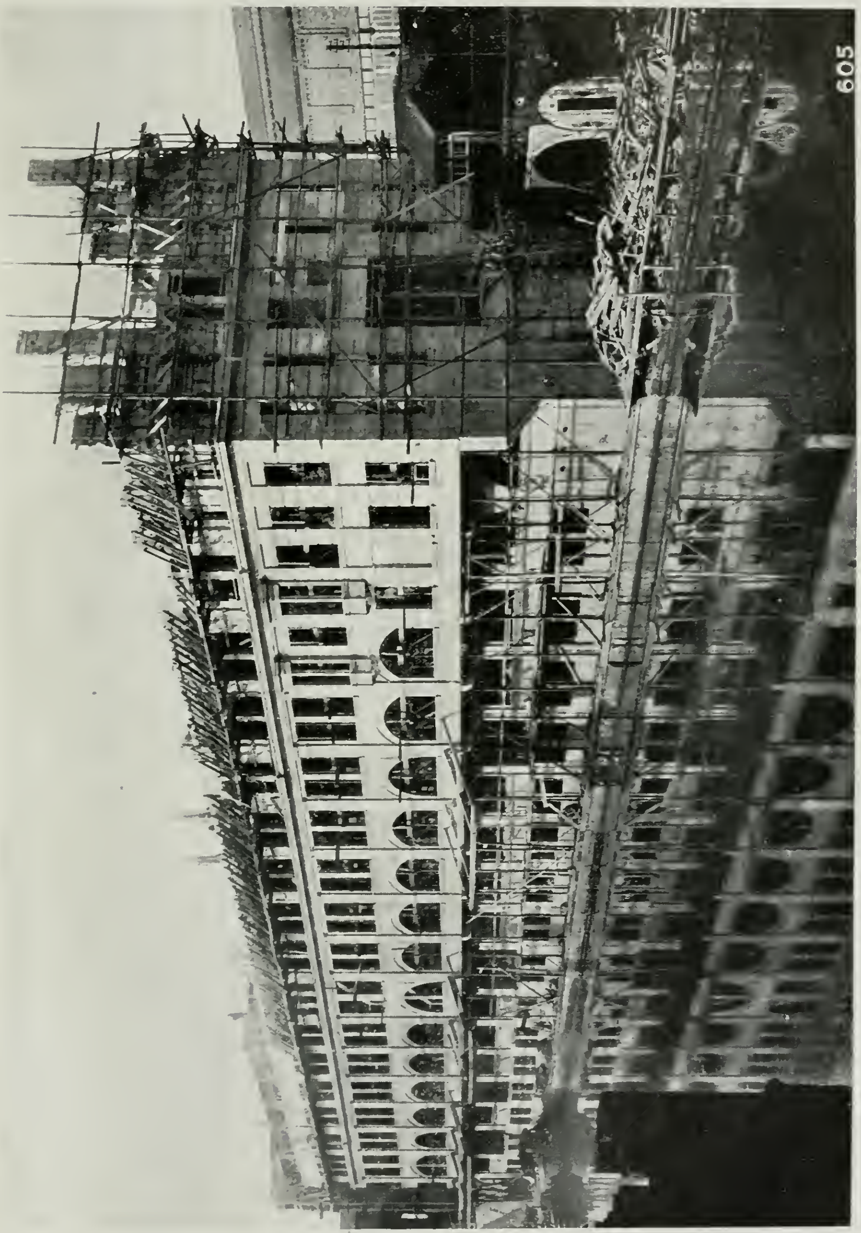


Fig. 1. Exterior View.
Reinforced-Concrete Warehouse, Manchester.

The plan (*Fig.* 2) and the sections (*Figs.* 3 and 4) show the building to be roughly 300 ft. long by 100 ft. wide, with nine floors and a flat roof. This roof has been designed to serve as a floor should extensions be necessary, and all walls and stancheons are designed to be strong enough to carry such extra loads. As will be seen in *Fig.* 3, seven of these floors are cantilevered out over the river 6 ft. beyond the lower floors, and the shelters for barges are also carried on reinforced cantilever beams united to the main floor beams and extending 15 ft. beyond the 6 ft. already mentioned.

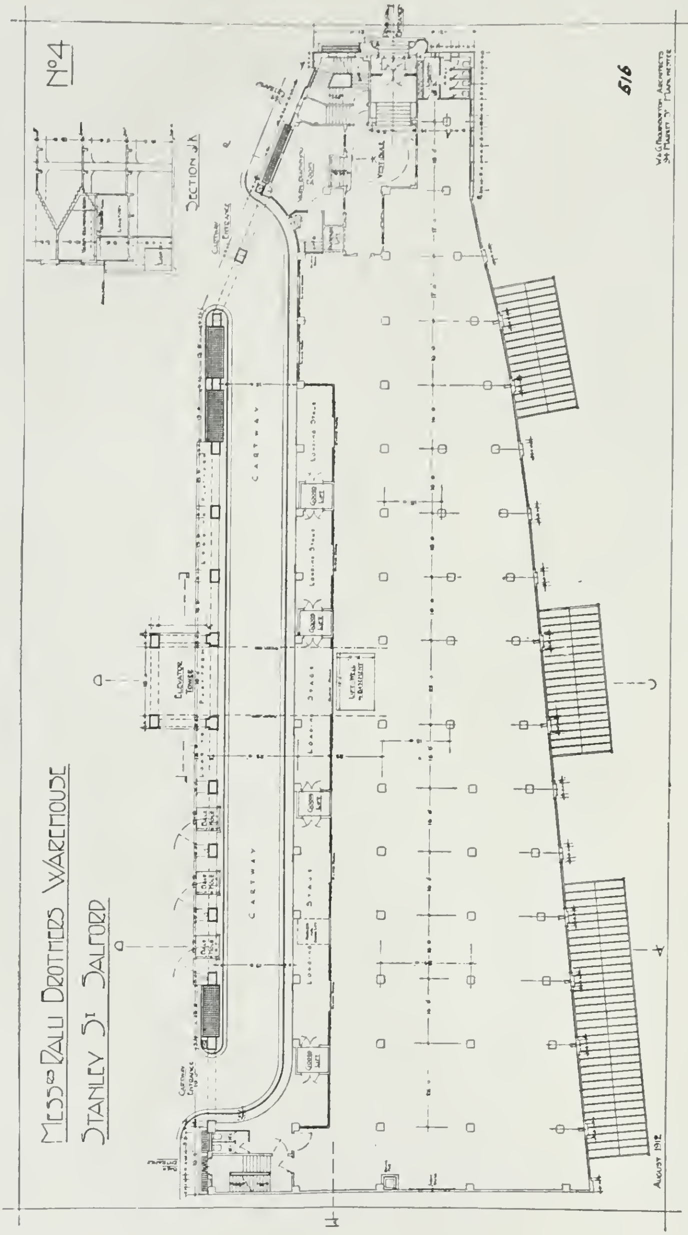


Fig. 2. Plan of Building.
Reinforced Concrete Warehouse, Manchester.

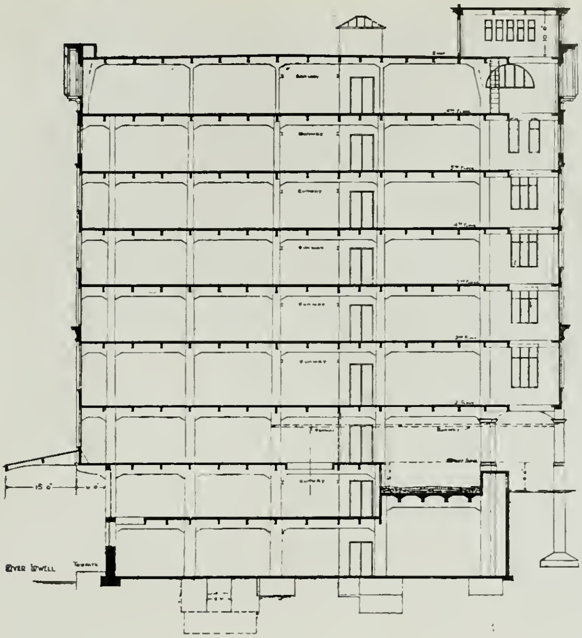


Fig 3. Section.

The purlins for carrying the glazing to these shelters and also the cantilevers on the street side of the building are of reinforced concrete construction.

Internally the building is constructed with main beams, 24 in. by 9 in., running across the building and with cross-beams 11 in. by 8 in. in the larger bays and 11 in. by 6 in. in the shorter ones. The goods dealt with are very heavy, and a "runway" is therefore provided over each floor and is carried by 14-in. by 7-in. beams. A transporter system is also installed in the building by which goods can be reached in every part, and this is connected with the lifts and the elevator tower, through which a railway siding runs.

On the ground floor a cartway is formed 19 ft. 6 in. wide and extending along one side of the building. This cartway is 5 ft. below the ground floor, which is also the level of the loading platform, and its position—(see *Fig.* 3) between two floors and the strength required for the loads it was to carry—led to some rather interesting construction.

Very deep beams were formed beneath the cartway, four subsidiary beams run at right angles to these and support a heavy slabbed floor, on which is formed the filling for the roadway, which is finished with granite setts. Between this cartway and the railway siding a bulkhead is formed in which baleholes are provided for dealing with goods direct from the trucks.

The first floor also possesses an interesting feature, in that it was desired to omit one of the stancheons to give a large,

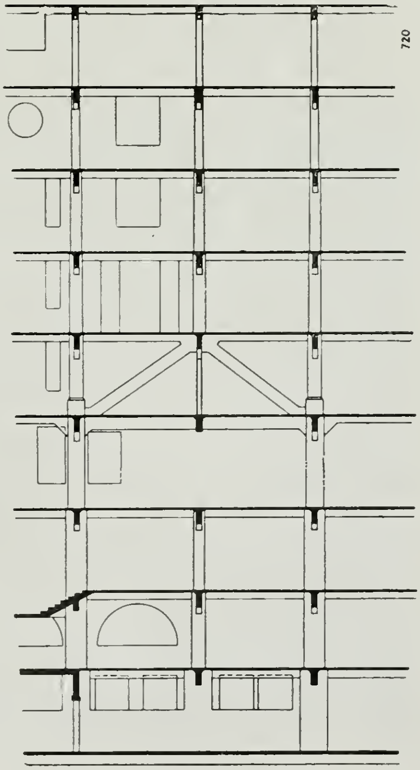


Fig. 4. Section.

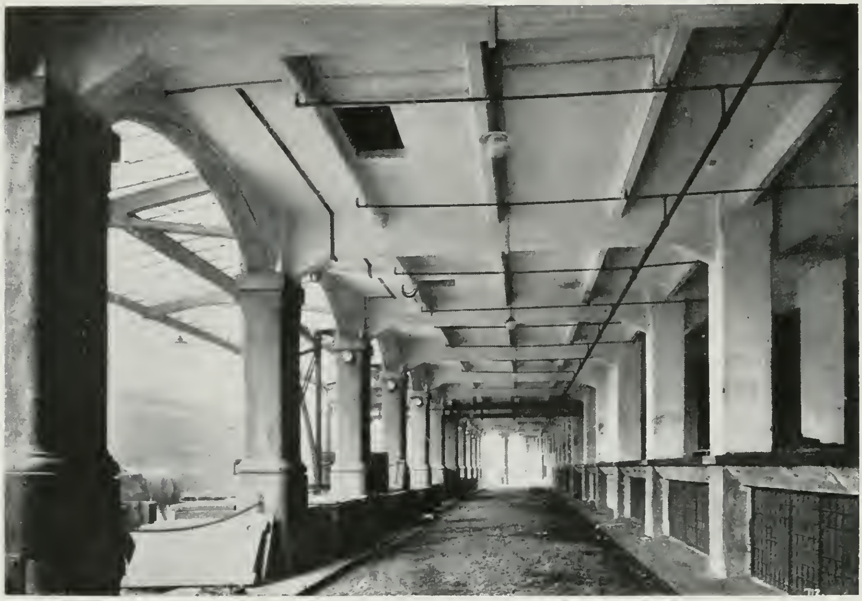


Fig. 5. Interior View.

clear, unobstructed office. *Fig.* 4 shows how this was carried out by forming a large truss on the floor above, and thus transferring the central load from the four floors above to the stancheons which run direct to the basement.

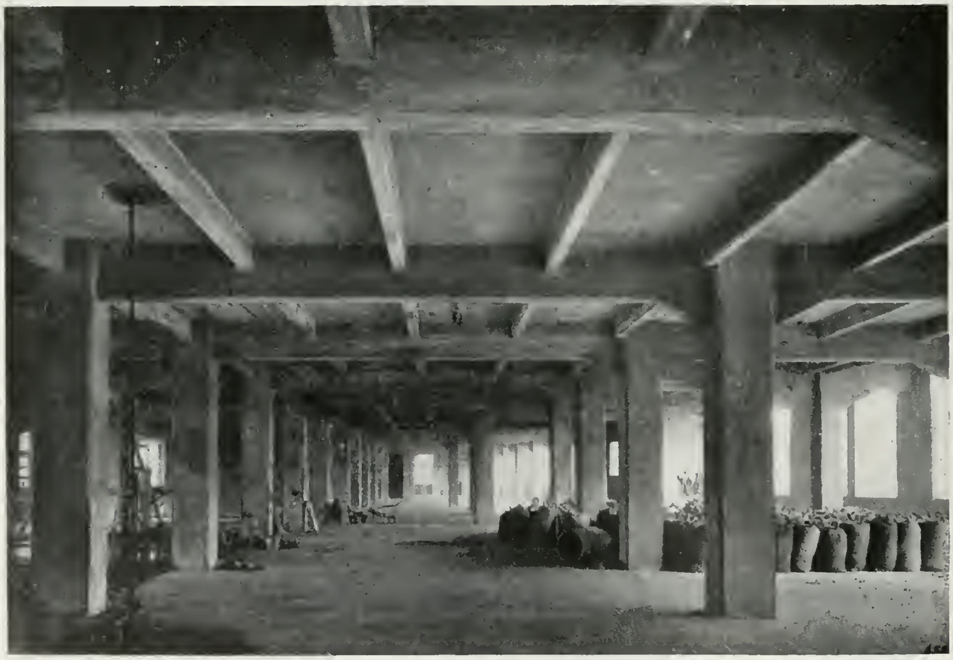


Fig. 6. Floor under Test.
REINFORCED CONCRETE WAREHOUSE, MANCHESTER.

After the building had been completed very stringent tests were carried out, and loads of 1·5 times the normal working loads were left for fourteen days upon the floors. The results of these tests, carried out on the largest spans, showed that the deflection in the main beams, 24 ft. long, was only ·01 in.

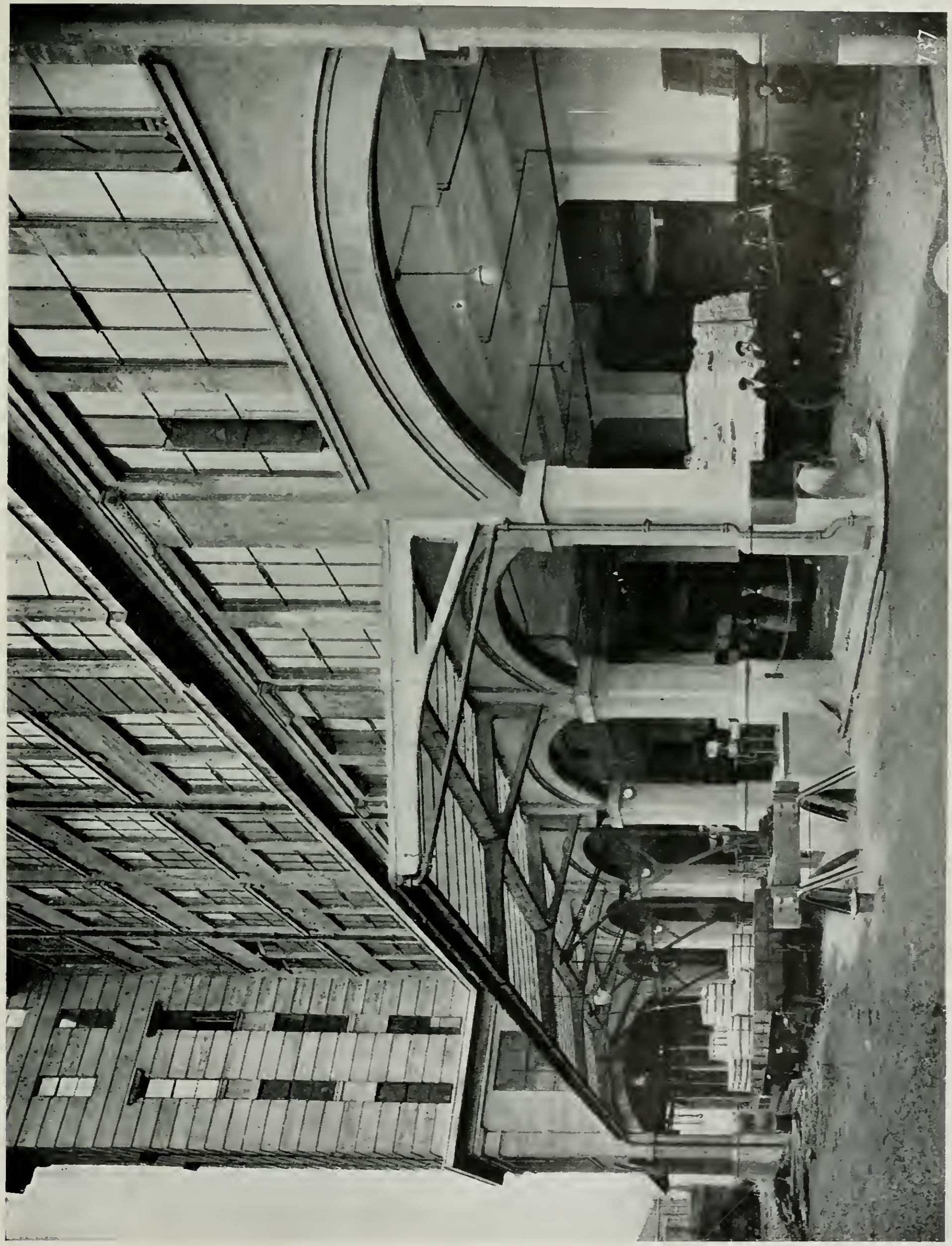


Fig 7. Another Exterior View.
Reinforced Concrete Warehouse, Manchester.

and in the cross-beams, 22 ft. long, but ·31 in. *Fig.* 6 gives a view of a floor under the test.

The architects for the work were Messrs. W. and G. Higginbottom, of Manchester, the contractors Messrs. Henry Lovatt, Ltd., of Wolverhampton, and the reinforced concrete work was carried out in accordance with the designs of The Indented Bar and Concrete Engineering Co., of Queen Anne's Chambers, Westminster, S.W.

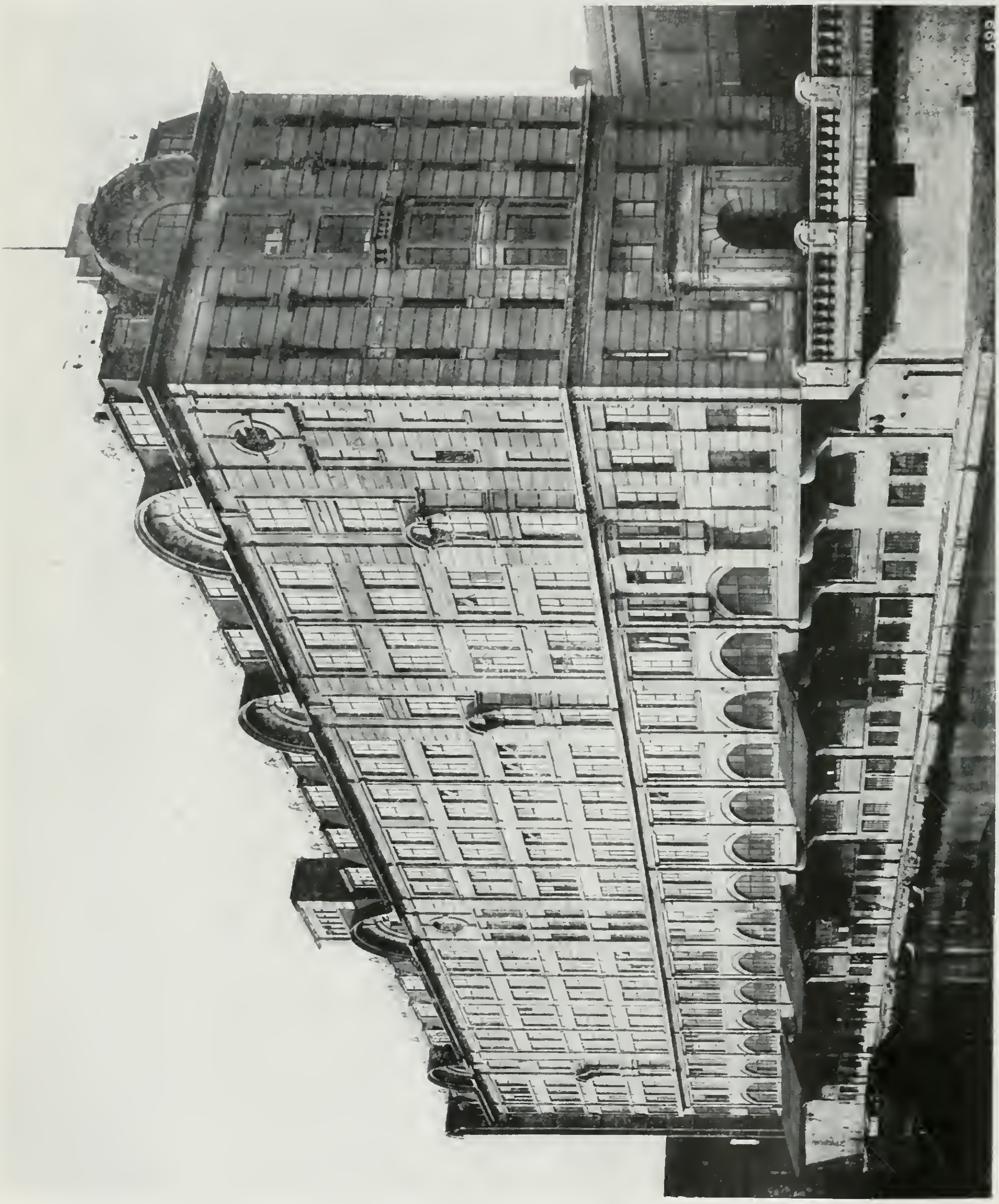


Fig. 8. Finished View of Building.
Reinforced Concrete Warehouse, Manchester.

TORSION STRESSES IN BEAM SECTIONS.

By OSCAR FABER, D.Sc.

The following short article should be read in conjunction with two articles which appeared in our February and March issues.—ED.

In the last two issues of Concrete most interesting articles have appeared on the above subject from the pen of Mr. E. S. Andrews, his articles being based upon, and explaining, the work of Messrs. Gibson and Ritchie.

It seems so unfortunate that when Mr. Andrews approaches a practical numerical example, as he does in your March number, he should make rather a bad slip, that I venture to correct it, knowing he would wish it corrected.

He considers the case of a 10 by 5 cleating into a 12 by 6, and shows a diagram, which I reproduce in *Fig.* 1, illustrating the forces as he considers them to act.

It is clear from this diagram that Mr. Andrews considers the reaction from the 10 by 5 to act at a point 3.57 in. from the centre of the 12 by 6 joist, this point being the centre of gravity of the four cleat rivets. This assumption has, of course, the advantage that the design of the cleat is very much simplified, inasmuch as the four rivets are then made to share the load equally.

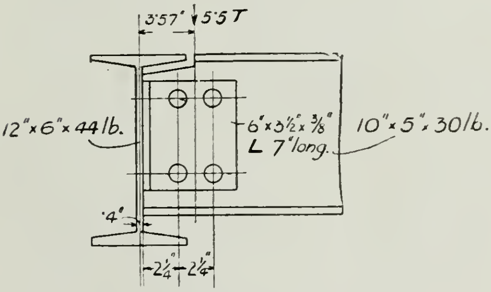


Fig. 1.

Unfortunately, however, the assumption also involves, as Mr. Andrews points out, the existence of so large a twisting movement on the 12 by 6 that the combined shear stress works out to 9.1 tons per square inch (I am accepting Mr. Andrews's figures), and Mr. Andrews remarks:

"This is nearly 1·7 times the stress allowed under the L.C.C. Building Act, 1909 Amendment, yet we believe that every district surveyor would pass the construction. The matter is sufficiently serious to demand the attention of structural engineers; either they should show the fallacy of the formula in question, or they should allow for the torsion stresses in their designs."

The logic of this last paragraph is indisputable, and I hasten to point out the fallacy. This lies in Mr. Andrews's assumption of the point of action of the 10 by 5. It is quite clear that the cleat can easily be so designed as to be strong enough to allow the point of reaction of the 10 by 5 to be carried on to a point as near the centre of 12 by 6 as matters for practical purposes, so that the torsion stresses are reduced to a negligible quantity.

This involves designing the cleat for a bending moment in addition to a shear, all of which was clearly explained in a paper I read before the Concrete Institute on April 16th, 1914.

There is no difficulty whatever in doing this, and it is always much cheaper to design the cleat for this moment than to design the main beam for a twisting action.

The condition of affairs would then be more like that indicated in *Fig.* 2.

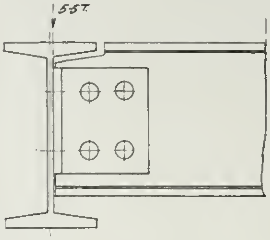


Fig. 2.

As a matter of interest, I find that even after allowing for all such bending stresses, the cleat shown in *Fig.* 3 will safely carry the reaction of Mr. Andrews's example with L.C.C. stresses, and is actually a cheaper cleat with three rivets instead of four.

The exact twisting moment to which the main beam is exposed is readily determined, when proper cleats are used, by the angle of slope at the end of the secondary beam, due to its own deflection, and its determination is so involved that if it had to be calculated for every beam, practical designing would take ten times as long as it does.

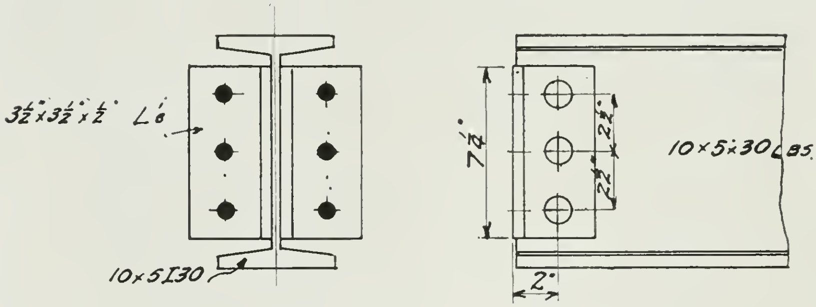
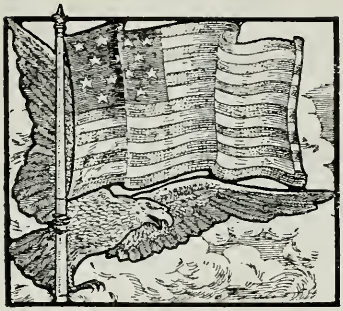


Fig. 3.

Fortunately, however, it is easy to show that it is very small, and if the cleat is designed for the whole moment as explained, the twisting moment in the main beam due to a joint of this type may be neglected with safety.

In conclusion, I may say that while Mr. Andrews's contribution to the treatment of combined twisting and bending of structural sections is both helpful and illuminating, there are, in my opinion, other factors to take into account which in many cases reduce the stresses considerably. These will be dealt with in an article now under preparation.

We are certainly all very indebted to Mr. Andrews, as to Messrs. Gibson and Ritchie, for opening our eyes to the weakness of structural shapes in resisting twisting, and to the dangers of beams bent in plan, which are obviously not appreciated in many offices.



RESISTANCE OF CONCRETE SEA WALL TO HEAVY STORM.

We give below a few illustrations and particulars regarding the protection afforded by a concrete sea wall in a severe storm which took place at Galveston, Texas, U.S.A. The illustrations have been kindly lent us by Mr. John S. Hawley, Consulting Engineer, Fort Worth, Texas, whilst our particulars have been abstracted from an article by Mr. E. B. Van De Greyn published in the "Engineering Record."—ED.

During the month of August last year a violent hurricane raged at Galveston, Texas, and considerable damage was done in the city, whilst the concrete works which flank the water front did excellent service.

The concrete causeway, two miles in length, which links the island city to the mainland, suffered heavily, its earth embankment approaches having been washed away, although the concrete arches forming the central portion of the structure withstood the violent and heavy impact of the waves. The city's water supply was cut off by the breaking of the pipe-line across the bay, and the demolition of frame houses within striking distance of the sea was general. None of the more substantial buildings in the city were wrecked.

According to the weather reports at Galveston, the velocity of the wind was at times 90 to 100 miles per hour.

The concrete seawall held intact, and undoubtedly saved the city. The causeway suffered considerably; the only portions which were left intact were the movable span at the centre, the concrete arches on either side of the span, and a portion of about 2,000 feet at the southerly end of the protected approach at the Galveston end.

The water supply of the city from Alta Loma is cut off by a break in the submerged pipe-line crossing the bay west of the causeway. The docks and wharves and elevators might be considered to be damaged to a minor extent compared to other damages. Some docks have only had a few planks ripped off The conveyors from some elevators were destroyed. One or two piers were reported destroyed.

A very great damage resulted from the water rising up in the stores in the business section and ruining the goods within. The height of the water in the city, as reported by different persons who were there in 1900, places it at from 6 in. to 2 ft. higher than in 1900.

In general the frame houses along the sea-wall boulevard facing the beach and for a little distance back were demolished or overturned. Substantial structures like the Galves Hotel were apparently uninjured, except for roofing metal torn off by the wind. Beyond the westerly end of the sea-wall the city was unprotected from the onslaught from the Gulf and the less substantial frame houses were swept entirely away.

The sea-wall, built in 1903, is 3½ miles long and is of concrete reinforced with 1¼ in. steel rods, as shown in the cross-section (Fig. 1). The concrete is carried by a wood pile foundation, and the outer or exposed face is curved to throw the sea vertically upward. The concrete base is 3 ft. thick and the wall proper rises 13 ft., giving a total height of 16 ft. to the concrete work. The toe of the wall is protected by a mass of heavy granite rip-rap, and the wall itself is backed by an earth fill brought to the level of the top of the wall and formed into a driveway about 70 ft. wide. The wall was designed by Mr. George W. Boschke, of Galveston, and built by J. M. O'Rouke and Co., of Denver, Col.

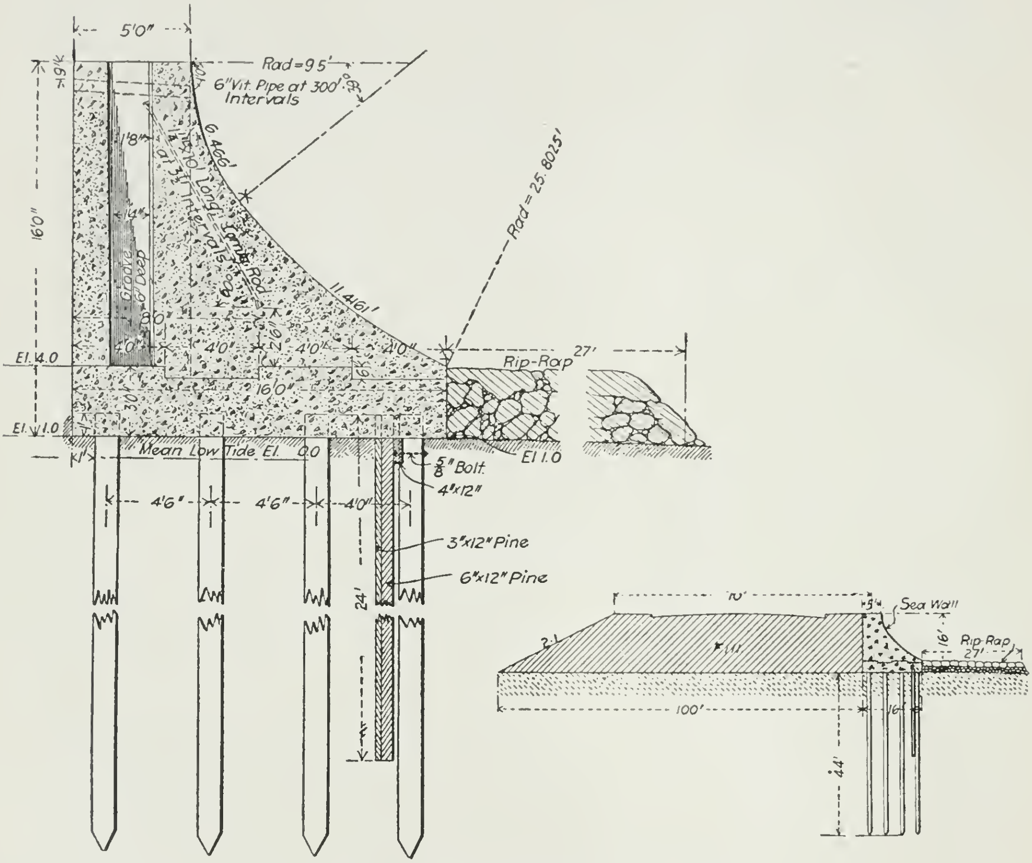


Fig. 1. Section of Reinforced Concrete Sea Wall.
Resistance of Reinforced Concrete Sea Wall to Heavy Storm.

An eye-witness at the sea-wall during the storm stated that the curved face of the wall caused the water to shoot straight into the air, and the wind would then throw the sheet of water on to the pavement behind the wall.

The sea-wall itself was not injured seriously at any point along its length. That it saved the city great damage, if not destruction, is sure. Beyond its

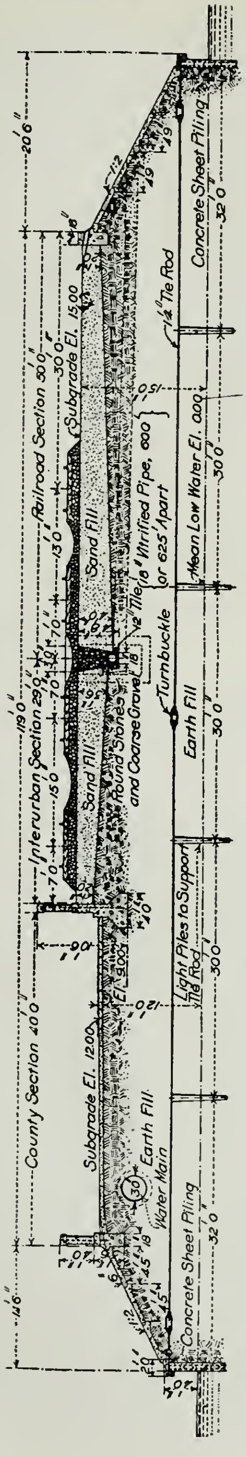


Fig. 2. Section of Earth Embankment Approach to Galveston Causeway which suffered heavy damage.

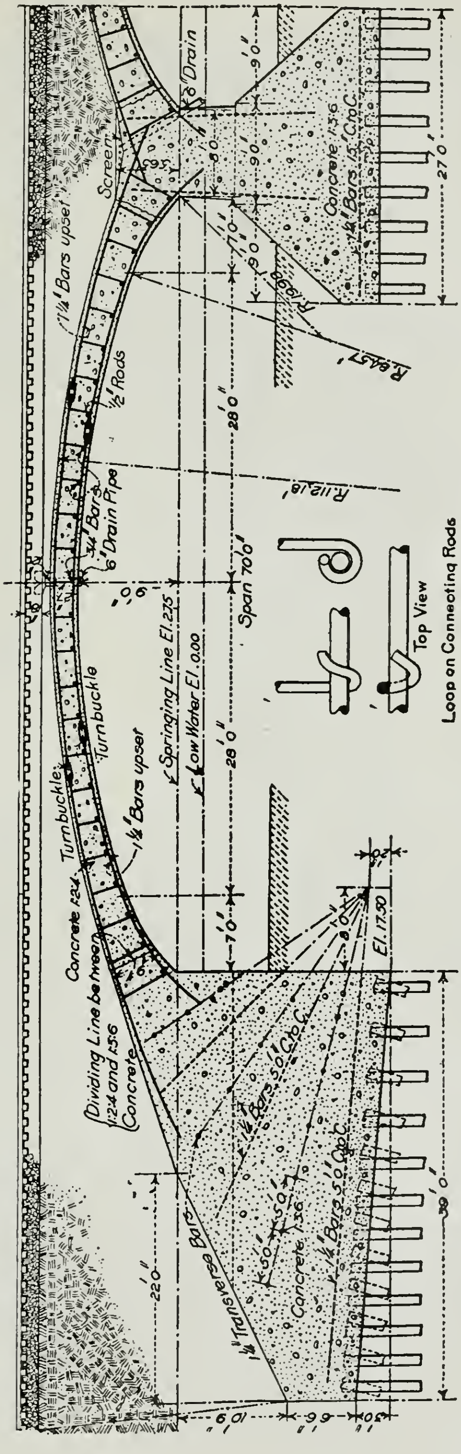


Fig. 3. Typical Section of Causeway Arch Construction which withstood the storm.
RESISTANCE OF REINFORCED CONCRETE SEA WALL TO HEAVY STORM.

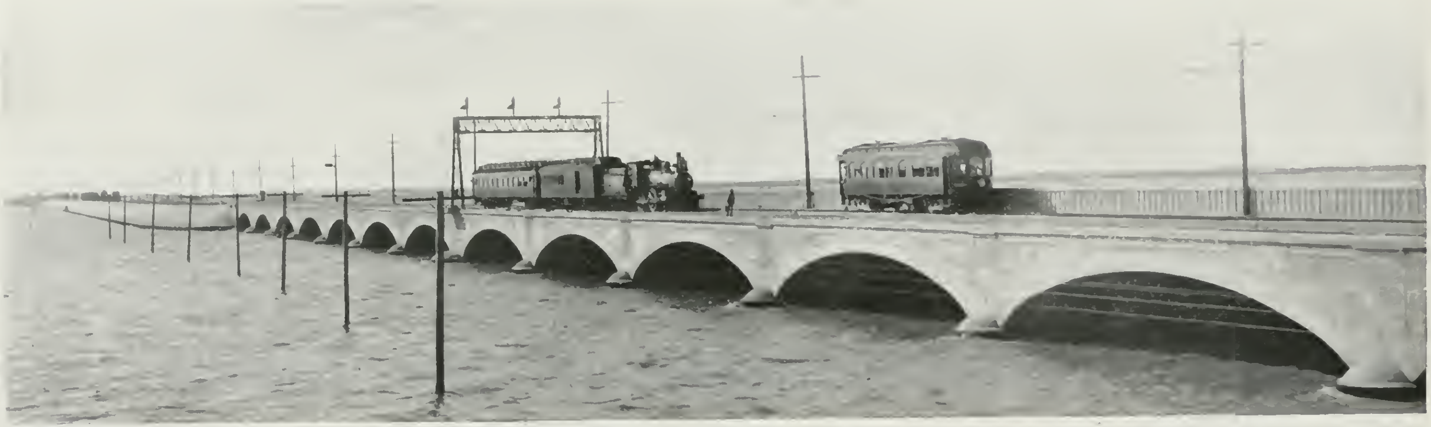


Fig. 4. The Reinforced Concrete Causeway at Galveston.

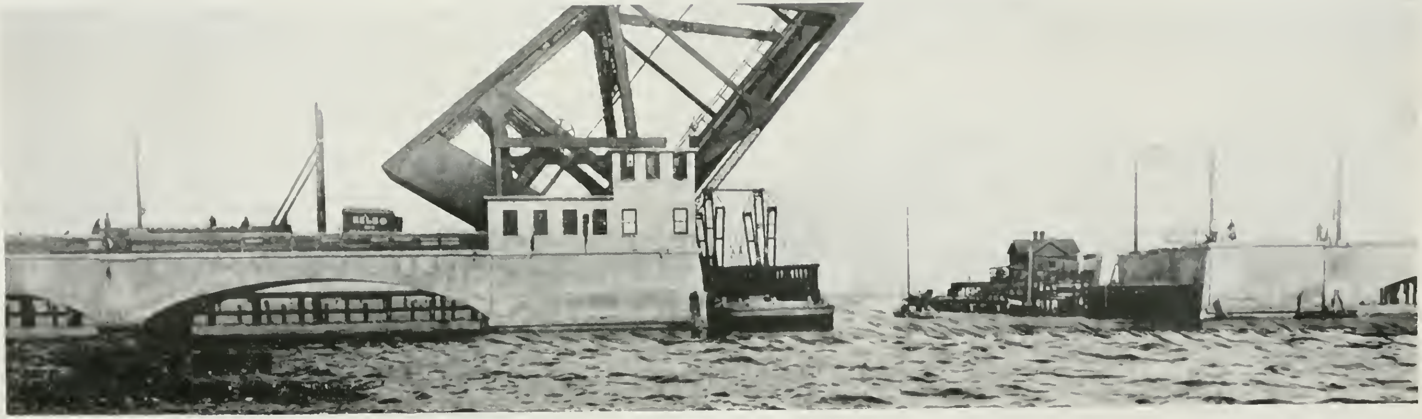


Fig. 5. The Lift Bridge on the Reinforced Concrete Causeway at Galveston.

RESISTANCE OF REINFORCED CONCRETE SEA WALL TO HEAVY STORM.

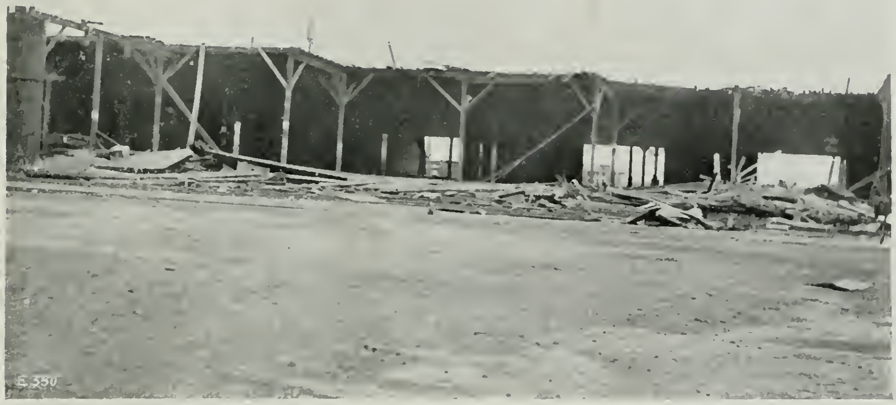


Fig 6. Wreck of a Shed on the Wharves.

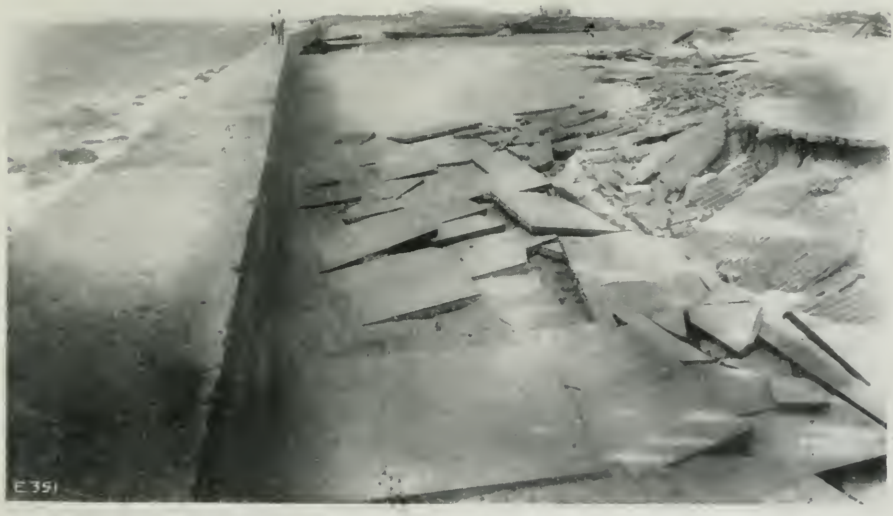


Fig. 7. The Sea Wall looking towards Fort Crockett.
(This is the only place where sand was washed from behind the sea wall.)

Resistance of Reinforced Concrete Sea Wall to Heavy Storm.

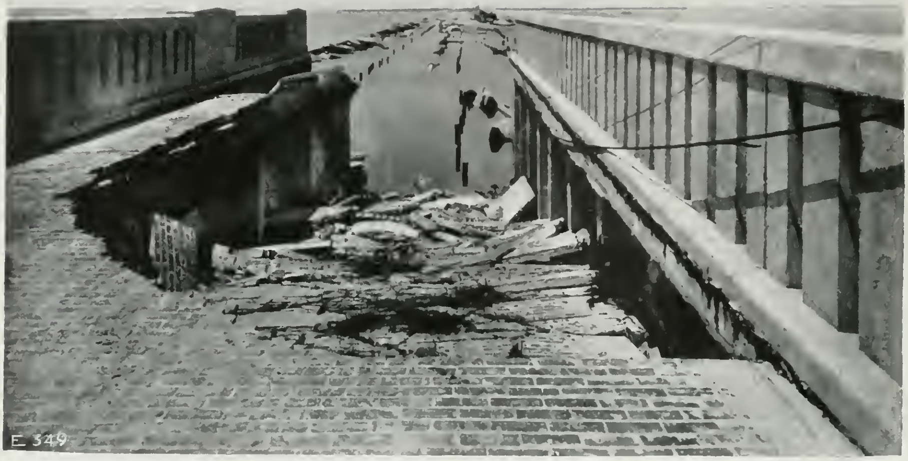


Fig. 8. View of a Wrecked Portion of the Causeway exposing the 30-in. water main.

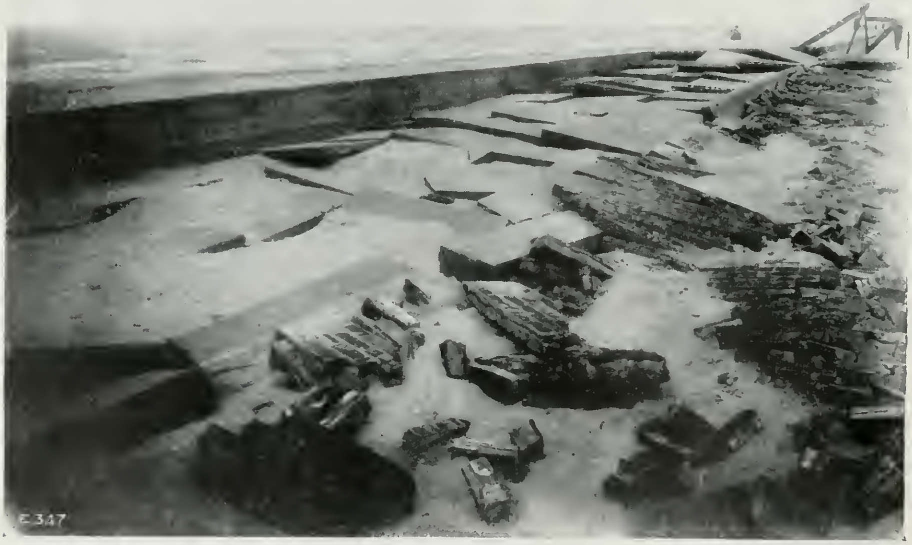


Fig. 9. Ruins of Paving Bank of Sea Wall.

Resistance of Reinforced Concrete Sea Wall to Heavy Storm.

westerly end, where there was no obstruction to the force of the waves, the country was swept clean of the frame houses which occupied that section.

APPROACHES TO CAUSEWAY WASHED OUT.

The movable span of the causeway and the concrete arches at each end of the span are intact. The north protected fill approach is demolished except for the toe walls on each side at the foot of the slopes, the toe walls being concrete sheet piling with concrete cap cast on top of piling. The south protected fill approach also is demolished except for about 2,300 ft. at the south end, which is partly destroyed.

Attention should be brought to the fact that the concrete slabs on the east side of the remaining part of the south approach were displaced. This is the side of the structure occupied by the steam lines.

WATER SUPPLY CUT OFF.

The main bringing water to Galveston from Alta Loma was discovered to have a break where it is submerged near the causeway. The work of repairing this break or of working out the proper solution to bring the water to Galveston was placed in the hands of the railway engineers. In the meantime drinking water was being distributed in city sprinklers from the suppiy that was on hand within the city.

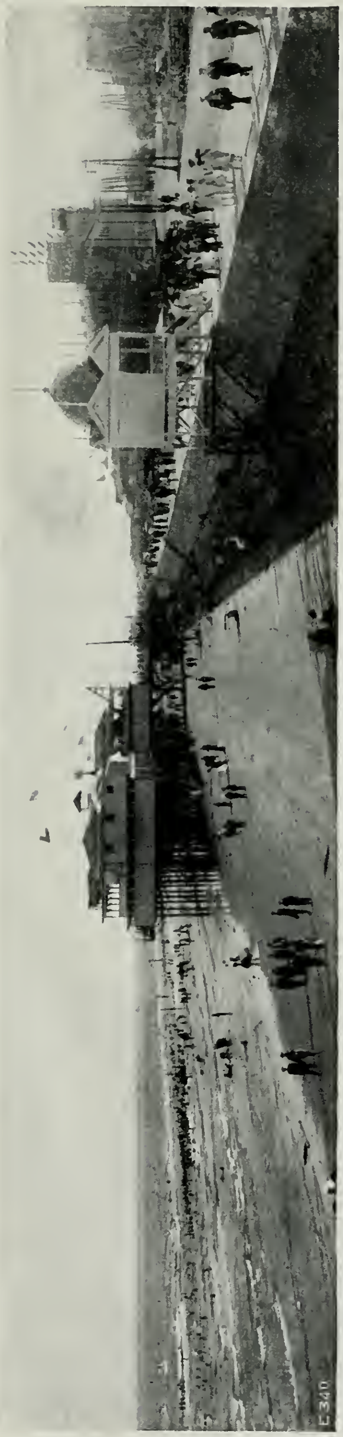
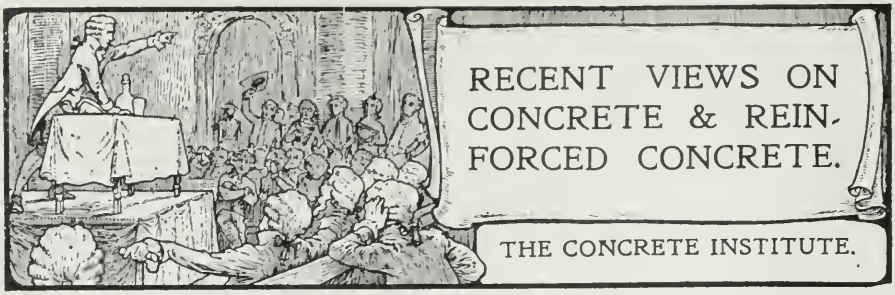


Fig. 10. The Galveston Beach and Sea Wall.

Resistance of Reinforced Concrete Sea Wall to Heavy Storm.



RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

THE CONCRETE INSTITUTE.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE CONCRETE INSTITUTE.

SOME EXAMPLES OF DANGEROUS STRUCTURES.

By W. G. PERKINS, M.C.I., District Surveyor for Holborn.

The following is an abstract from a Paper read at the Sixty-seventh Ordinary General Meeting of the Concrete Institute on Wednesday, March 15th, 1916. The author gave numerous examples and illustrations which it is quite impossible for us to reproduce here. A short résumé of the discussion is given.

AMONGST the causes of a dangerous structure are the following: (*a*) Faulty construction; (*b*) faulty materials; (*c*) faulty design; (*d*) decay and fatigue; (*e*) overloading; (*f*) removal of extraneous support; (*g*) wind pressure, shock, etc.; (*h*) fire and explosion, bombs. Generally speaking, several of these causes occur at the same time, particularly (*a*), (*b*), and (*c*).

Perhaps few of us have had any experience with failures arising from faulty design and materials in modern structures, as a sufficient period has not elapsed for time to have done its work, but there are numerous instances in buildings erected by former generations.

The bricks were badly shaped and easily broken, so much so that in taking down old walls one finds course after course of what appeared to be headers to be only "bats." This resulted in the walls being built in a series of "half brick" or 4½-in. skins which sooner or later separated and bulged, and many a dangerous structure is due to this cause alone.

Generally speaking, this bulging occurs in the basement story immediately below the level where the thickness of the wall diminishes by means of a "set off" from one thickness to another, say 1 ft. 10½ in. to 18 in. The phenomenon of failure at a sudden change in thickness is referred to by Professor Ira O. Baker in his work on "Masonry Construction," p. 314, 10th edition.

Sometimes large portions of brickwork roughly triangular in elevation and wedge-shaped in section burst from the walls, and when this is the case no time should be lost in needling the walls well above the point where the failure shows itself.

In many old buildings the main beams of the floors are placed diagonally and the loads from the roof and four stories are imposed upon a pier of brickwork about 14 in. square. Needless to say, such piers have crushed.

Several cases I have dealt with have been party walls built with the bricks and mortar before described, about 50 ft. in height from the basement floor line to half-way up the gable. They have failed by crushing in the basement, although the load consisted of only their own weight and that of the dwelling-room floors and furniture on them.

A form of construction frequently found is a shell of 4½-in. brickwork around a stout timber post. You see the brickwork bulging and wonder why a stout-looking pier, perhaps 2½ bricks square and 8 ft. in height, should be failing under a comparatively light load. The explanation is that the timber post has decayed at its lower end and the thin shell of brickwork is unable to carry the superstructure.

Cement Grouting.—A very interesting case of this kind was a building near Queen Square, Holborn. Having occasion to inspect the premises, I found the piers were cut into and timber posts rotten at the ends were disclosed. These posts extended up to the second floor, and were quite sound in the upper parts.

Sir Francis Fox was consulted by the owners, and it was decided to grout the whole of the walls with Portland cement. Numerous small holes were cut in the interior faces, just large enough to insert the nozzle of the grouting machine. After well soaking and washing the interior of the wall with clean water under pressure from the machine, Portland cement grout was pumped in, and as it appeared at the joints and cracks it was dammed with clay stuck upon the faces of the wall by workmen watching for its appearance.

The whole of the walls were treated in this way with success. Prior to the grouting they sounded hollow, but they now sound and have every appearance of being solid. After the grouting the wooden posts were cut out of the piers and substituted by brickwork in cement.

Modern brickwork is not without its faults, due principally to the lax manner in which it is supervised and an imperfect knowledge on the part of the specification writer

Many people object to slate damp-proof courses, as they become inefficient owing to the slates cracking. They only crack or crush when they have been imperfectly bedded. The usual way is to lay them on a bed of cement (perhaps containing a number of small stones) and tap them down with a trowel. This always results in the centre of the slate being unbedded. Use cement made with a sand that contains no small stones, rub each slate well into its bed, and you will get a damp-*proof* —not a damp—course.

I am not partial to asphalt damp-proof courses unless they are of genuine asphalt. Artificial asphalts are brittle when cold but become soft in the heat of summer or near a heating chamber, and squeeze out. Failures have occurred by using unsuitable materials in the composition of concrete.

There was the case of the reservoir where blast furnace slag was used as the aggregate for its concrete walls. The water affected the concrete so that it became quite soft and rotten, and the walls had to be rebuilt.

Fletton bricks, as our Past President, Mr. Wells, has pointed out, do not make reliable concrete owing to the large amount of calcium sulphate they contain. When this sulphate is in the form of small nodules walls built with such bricks will soon become dangerous. One well-known architect had to deal with a church whose walls became rotten and bulged in consequence. At Dalston, Clapton, and in the Kingsway I have condemned such bricks, and they crumbled away before they could be removed.

Coke Breeze.—Concrete made with breeze is a dangerous material. It is one of the materials specified in the London Building Acts as a fire-resisting material, and as a district surveyor I have, much against my better knowledge, to pass it. This stuff was used for the floors of sculleries in the first stories of a row of houses built under my official supervision. In every house this stuff expanded, pushing out the walls, some of which had to be rebuilt.

In another district I had to inspect a block of residential flats, the walls of which were bulged at every floor level owing to the expansion of the breeze concrete.

If you use broken brick for concrete see that it is free from any old plastering, etc. Provided this aggregate be quite clean, it is one of the best for floor work.

Fire escape balconies should not be constructed with concrete made of coke breeze Being exposed to the weather they are peculiarly liable to be affected, and would fail perhaps just at the moment they had to be used.

The term " foundation " is sometimes used in a very indefinite manner, and may mean the actual base upon which the superstructure is reared or the soil itself. When terms such as " bad foundation," " rock foundation," are used, the nature of the soil is evidently referred to; whilst should the term " concrete foundation," " piled foundation," or similar term be used, a form of sub-structure is meant. Why should not the Concrete Institute take the lead, as it has in the case of Standard Notation, and give some of the terms in common use a definite meaning?

Foundations.—Foundations are important, as when defective or insufficient they will lead, sooner or later, to a dangerous structure.

If a structure has become dangerous owing to insufficient foundation or a bad foundation bed, we must, before proceeding to apply any remedy, ascertain the nature and bearing capacity of the soil upon which we may have to place our load. Methods of ascertaining this capacity are given in Professor Ira O. Baker's "Masonry Construction" and other text-books. If you are dealing with a clay soil it is useless to construct your foundation at any depth less than 8 ft. below the surface of the ground, for the drought of the first fine summer will affect the soil to this depth.

If the walls of your structure are upright, in long lengths, and you intend to use an ordinary spread foundation of concrete, or perhaps concrete and brick footings, to comply with a by-law, you may undertake the work in short lengths without any shoring, but take care that the soil you have to excavate through will not escape laterally, as it may if wet, or in the nature of running sand. In some underpinning recently done in this way the sides of the excavation in the London clay would not hold up half an hour, but fell out in cone-shaped masses before the poling boards could be put in. In such cases it is always advisable to shore with raking shores.

If your structure is supported by piers or columns the superstructure must be carried for the time being upon needles and dead shores, and prevented from getting out of upright during operations by raking shores. Flying shores are also useful when an abutment not too far off can be obtained.

In dealing with structures rendered dangerous by settlement owing to the insufficient bearing capacity of the soil, I prefer, wherever there is an underlying stratum of firm material, to sink down to it, even though it should be at a considerable depth. The sinking should be in the form of pits (the area of which would be determined by the loading and the bearing capacity of the firm material), filled up with good mass concrete. Then from pier to pier either construct beams of reinforced concrete or fix rolled steel joists, encased in a rich and well-graded concrete or turn arches.

I am not an advocate of raft foundations, for unless your structure can be symmetrically disposed about the raft or its centre of gravity be made to coincide therewith—a very difficult thing to do except in a symmetrical building—the pressure on the soil will be unequal, the raft will tilt and throw your structure out of the perpendicular.

In the case of a newly-built warehouse, when the first tenant commenced to move in the floors and roof in the centre of the building sank to an extent of something like 7 in., the steel joists deflected, crushed the stone templates, and pushed the walls out of plumb.

It was found that the internal columns had no bases, in the ordinary sense of the word, but lugs, the templates being pieces of old flagstones.

These lugs had broken off and the shafts of the columns had crushed through these templates into the cinder concrete "foundations." It cost a large sum to make the premises secure by the insertion of steel joists and stanchions, with foundations of good concrete carried down to solid ground.

Removing an important part of a structure will speedily render it dangerous. A case in point is the cutting away of the inclined member of a framed partition to form a doorway. This is an alteration occasionally made when replanning old-fashioned houses.

In a two-storey building with a roof which overhung on one side 10 ft. 6 in. the tie-beams of four out of eight roof trusses were cut away at some time. The whole building was drawn out of perpendicular, the wall next the overhanging portion of the roof becoming 13 in. and the other 8 in. out of plumb.

A bressummer supporting three stories was cut away to accommodate a revolving shutter.

I have lately seen the top flange of a steel joist entirely cut away and chases 2 to 4 in. deep formed in 6-in. reinforced concrete floors at right angles to the reinforcement for the full breadth of the slabs for the purpose of running electric wires.

Overloading. — Dangerous structures caused by overloading are generally due to the occupier crowding his premises with stock. A warehouse had been filled from floor to ceiling in every storey with sacks of seed.

A brick pier just below the level of the ground floor which supported the columns carrying the floors and roof failed by crushing, which resulted in the collapse of practically the whole building. No doubt in this case faulty design and faulty construction considerably contributed to the failure, but the pier had done its work for fourteen or fifteen years, and had the occupier consulted a professional man before filling his warehouse the accident doubtless would have been avoided.

The floors and roof of this building were constructed of reinforced concrete, and it was instructive to note that where the concrete was solid and dense the steel was well preserved. It had almost entirely rusted away where the concrete was less dense or contained voids.

With regard to overloading, there is the well-known case of a football stand, where failure occurred by seventeen of the deal joists supporting the tiers upon which the public stood breaking at the point where they had a bearing over the first of the intermediate supports, counting from the higher end. These joists were spaced 4 ft. from centre to centre and were continuous over one support, thus having two spans each measuring 12 ft. on the horizontal. The joists were 3 in. wide by 8 in. deep, and were notched over the central bearing, leaving a working section 3 in. by 6 in. This point would be that of maximum bending moment.

Each joist supported ten rows or tiers, which, allowing 16 in. per person, would provide standing room for thirty people. Had each of the persons grouped at this particular spot weighed as much as 11 stones, each joist would have had to support nearly 42 cwt. of crowd. Adding to this 3 cwt. for the actual weight of the joists and flooring, the total load on each joist was 45 cwt. This is equal to 126 lb. per square foot, without any allowance for movement of the crowd and vibration.

The records of the London County Council, if available, would show many cases of failure by overloading the floors in buildings of the warehouse class.

Removal of Extraneous Support. — Digging trenches for drains and sewers without sufficient timbering has been a fruitful source of dangerous structures. Many a wall and building has collapsed from this cause.

In the same category come excavations, such as for the sub-basements and basements of new buildings, which may be 40 ft. deep or more, and here, again, particular attention must be given to the shoring, especially when the street is a narrow one and there are buildings on the opposite side.

Unlike a trench, an excavation for a basement may be too wide to strut with horizontal timbers, and as you dig so you remove the soil supporting the feet of any timbers inserted when the work was first started.

Any considerable movement in the shores allows a subsidence that will cause a fracture of the water main; there will at once be a washout—electric cables and gas mains will be broken, the electric current setting fire to the escaping gas, followed most probably by the collapse of buildings contiguous to the excavation.

Except the collapse of the buildings this actually happened in a well-known London thoroughfare. And in another important street it was only the prompt action of the district surveyor which prevented such a collapse.

In the first case the excavation had reached a depth of about 20 ft. below the street level for a length of 50 ft., and had been strutted with 7 by 7 in. timbers, some 18 ft. long, spaced 14 ft. centre to centre. The attention of the foreman had been called to the inadequacy of this timbering, but steps were not taken in time to prevent the failure.

In the second case the district surveyor wrote to the contractors, but, having no jurisdiction, could take no action until the buildings were rendered dangerous.

I suggest that the best way of dealing with such excavations is to dig a trench, timber it in the ordinary way, and brace such timbering; then build your retaining wall and afterwards excavate the " dumpling." You can do the work in sections if it is impossible to dig the trench for its full length at once.

Occasionally a water main will burst, filling vaults under the roadway and basements of houses, bulging and fracturing the arches and head walls of the former and the party walls of the latter.

The presence of an old well or cesspool, planked over and covered with earth, long forgotten and then built upon without troubling as to the foundation bed, has often led to trouble.

After several old houses in one street had been condemned as dangerous structures, the owner of his own accord took down the remainder of the row. When digging trenches for the foundations of the new houses that were afterwards erected on the site, literally dozens of such cesspools were found, two of them sometimes adjoining.

The construction of subways and railways in tunnel, tube, or cutting may account for many settlements in buildings adjacent to the line of route by actual movement of the soil or by withdrawal of water from the strata.

Wind Pressure.—Wind is a frequent source of dangerous structures. Formerly its action seems to have been disregarded by designers, but the Tay Bridge disaster brought its reality home to the authorities, and it is now always allowed for in bridges and other important structures. Even to-day in buildings enclosed with walls of the thickness specified in local building acts and by-laws no account is taken of wind pressure. In the South of London I have seen a modern building which collapsed during a gale The cast-iron column which supported one angle of the premises broke into four pieces at the time of the collapse, but this may have been caused by its fall to the ground or the falling *débris*.

During the gale which occurred on December 14th, 1907, one of the legs of a Scotch derrick crane about 117 ft. in height, used in the erection of a large building not far from here, became affected by the wind, and the whole of the structure, together with the platform and crane, the jib of which was about 60 ft. in length, commenced to sway. Before eleven o'clock the crane, according to the *Daily Telegraph,* was swaying 5 to 6 ft. in the wind, and threatened every moment to collapse. Notwithstanding the immense risk, guy ropes were attached by the contractor's workmen to the defective leg, and made fast to the stanchions of the building, which extended down to the sub-basement.

The primary cause of the leg becoming defective was, I believe, the soaking of its foundations by heavy rains.

The London Building Acts Amendment Act, 1909, requires a steel-frame building to be so designed as to resist safely a wind pressure in any horizontal direction of not less than 30 lb. per square foot on the upper two-thirds of the surface exposed to wind pressure. Even this is objected to by architects of the "old school," who urge that in London buildings are so close together that the wind pressure cannot attain this figure. I have, however, seen a long fence wall, 14 in. thick and 10 to 12 ft. in height, blown down. Working this out, neglecting the strength of the mortar, you will find that the pressure must have been in the neighbourhood of 15 lb. to the square foot. And this was not a lofty structure, but one near the ground, with trees and hedges close by on the windward side.

During the gales which occurred in the first week of January this year the roofs of buildings at Tooting and Hanover Square collapsed, chimneys were blown down, and a vast amount of damage done to buildings throughout the country.

Fire, Explosion, Bombs.—I need hardly say anything with regard to fire—its effects have so often been described and illustrated.

During the raids last year explosive bombs were dropped in certain places, but it is perhaps inexpedient to discuss the result yet awhile, as the authorities would object

My experience with gas explosions has been limited to minor cases which resulted only in the fall of plaster ceilings, so that I look to some of you for information under this head.

The Secretary has suggested that I should deal with "earthquakes and the like." I have had no experience of earthquakes, but I recollect that in 1893 a landslide occurred at Sandgate. The disturbance was felt along the foreshore for a length of about 2,800 ft., and extended on to high ground for a short distance inland. Between high- and low-water marks there were visible signs of a slight upheaval, a layer of blue clay being obtruded through the line of fracture, with fresh water in some places issuing from the crack.

It may be asked, What constitutes a dangerous structure? I must confess I cannot give a direct reply. It depends entirely upon the circumstances. The whole of the facts that have, or may have, any bearing on each particular case must be examined.

Taking a wall as the simplest case, we must see whether it is out of plumb and how much, whether it is low or high, tied in at frequent intervals by floor joists or beams, or whether there are no ties at all, as is sometimes the case in a flank wall, whether it has lateral support in the shape of return walls or chimney breasts, and if so at what intervals apart, also the general condition of the masonry, whether cracked, bulged, unbonded, built with poor or bad mortar, the nature of the foundation upon which it rests, or which experience in the locality shows it is likely to have or not to have.

DISCUSSION.

The President, said that he did not remember a paper upon the same subject before at any Society, and its novelty made it all the more welcome. It had been his lot to come across a great many failures from faulty design in modern structures, church and other large roofs, from the trusses being badly designed and insufficient allowance made for thrust; retaining walls, from want of knowledge of principles of stability; arches, from ignorance of the stresses produced; girders, from inadequate riveting, cover plates too short, depth insufficient for the span, etc.; tall chimneys, from insufficient foundations and allowance for wind; tanks, from badly designed joints, and many other varieties of error. In fact, where an architect was his own engineer, it was somewhat difficult to find a building wholly free from criticism as regards its structural stability.

The bulging of basement walls below a set off was due in most cases to the set off being on one side and consequent upon the eccentricity of the loading, but it might be aggravated by the pressure of earth on the other side. On the upper floors, the weight of brickwork nearer the outer face and the floors at the inner face tended to equalise the pressure at an inside set off.

As regarded brickwork running to more than 12 in. for four courses, it should be borne in mind that bricks from the Midland counties were larger than those made in the South of England. The vertical joints inside a wall might be properly flushed up by larrying, or by grouting, if carefully done. The condition of the stone piers supporting the dome of St. Paul's Cathedral showed what might happen when the interior joints were not filled up solid.

He agreed with the author that the lax use of the word "foundation" should be corrected and that this term should mean the artificial construction prepared to support the superstructure, whilst the soil beneath should be termed the foundation bed. He also thought that, upon a clay soil, the foundations should be deeper than usual.

In his opinion it was not possible to calculate the thrust that raking shores had to resist, but it was a simple matter to calculate what any given system of shores was capable of resisting. The limiting factor was generally the weight of brickwork above the needles contained in an inverted equilateral triangle.

In conclusion, he thought the feeling among those who had often to deal with dangerous structures was, not that there were so many actual failures, but why there were not ten times the number.

Mr. A. Dovaston, of the Dangerous Structures Section of the London County Council Architect's Department, in proposing a vote of thanks to the author for his very admirable paper, said, on behalf of Mr. W. E. Riley, the Head of the Department of the London County Council, how much that gentleman regretted that he was prevented from attending the meeting. On behalf of Mr. Riley, he was authorised to offer some notes on the subject matter of Mr. Perkins's paper which might be of interest to the meeting. Mr. Dovaston mentioned that some time ago he made a comparative analysis of some of the regulations which had been framed from time to time since the Great Fire of London, relating to the construction of buildings in London, and the result of this might account, to some extent, for dangerous structures in London.

In the year 1679 an Act was passed for the rebuilding of the City of London, and since that date some fourteen amendment Acts had been passed affecting the construction of the buildings in that and neighbouring areas. The provisions of the earlier Acts were directed to secure the use of materials which offered better resistance to the spread of fire than the old timber-framed buildings existing at the time of the Fire, but until 1855 no serious attempt was made either to regulate the manner in which these materials should be put together or their quality as regards durability.

In 1774 an Act was passed which had for its object the better regulation of "buildings and party walls" and "for the more effectually preventing mischief by fire" not only within the City, but also in certain specified parishes around the City and covering an area about 46 miles in extent, and extending to about a four-mile radius of St. Paul's Cathedral, and this Act remained in force until 1844.

This Act dealt with the question, as its title indicated, to a great extent from a fireman's point of view, and required the external walls or internal enclosures to be of brick, stone, lead, copper, tin, slate, tiles or iron, and contained an astonishing provision which allowed the use of what was described as "the necessary planking for the foundation" of the walls.

The provisions of the Act of 1844, which remained in force until 1855, were made applicable to houses within an extended area of 117 square miles, it being practically the same as that of the County of London to-day, and, although it made a step in the direction of obtaining a better form of construction by specifying the thickness of the brick walls, there were no restrictions whatever as to the quality of the materials or the workmanship.

The Act of 1855 was also weak in these requirements, but it *did* require that the bricks should be properly bonded and solidly put together, and the return walls to be properly bonded together, which was an important provision as regarded front walls and parapets of buildings. By this Act the walls could be erected on a layer of concrete of an unspecified quality and thickness or width, as an alternative to solid ground, which doubtless brought about a weakness in the walls constructed under this regulation.

By-laws of 1878 embodied in the present Act of 1894 required that bricks for external walls should be good, hard, sound and well-burnt; that mortar and cement should be "good" and of a certain specified composition, "and that foundations shall be of lime or cement concrete of a specified composition, width and depth, and it can reasonably be expected that the rigid enforcement of these provisions should, to a large extent, minimise dangerous structure cases in the future."

Of the 6,000 odd dangerous structure cases dealt with in 1911, about 66 per cent. arose within the area limited by the four-mile radius of St. Paul's, and the condemnations have, to a large extent, arisen owing to the fact of the greater part of that area having been closely built upon before 1878 without being subject to the provisions enacted at that date for ensuring greater stability and durability, to the disturbing effect of the vibration set up by the heavy motor traffic in recent years on such badly constructed buildings.

Mr. G. H. Blagrove said that one thing had struck him in connection with new buildings—he had never yet met with a modern bricklayer who would fill his perforations with mortar, and he thought that there they might perceive one of the causes of future danger in modern new buildings. He supported the vote of thanks to the author.

Mr. Osborn C. Hills, F.R.I.B.A., said that architects were frequently criticised, sometimes without justice. He instanced two or three cases where dry rot had set in and the architect had had to pay the cost. In cases where the architect took no trouble to provide proper ventilation and so on, there was no doubt that he ought to stand the racket, but dry rot was a germ or spoor that could be developed under circumstances over which the architect had no control whatever, and no examination by him could detect it until probably two or three years had passed.

Mr. S. Bylander was surprised that there were not more failures, considering the stresses which were induced in many structures. Particular care should be taken to prevent bad conconstruction, and it was more important to take steps to ensure effective construction than to limit the working stresses.

Mr. Allan Graham, A.R.I.B.A., mentioned that in his experience of well-known estates in the West End he had found that a good deal of the middle brickwork was very defective. In his judgment, the average brickwork nowadays was superior to the brickwork of the Georgian period. In many of Nash's buildings they came across magnificent pillars, the centres of which were scaffold-poles with brickwork built around them. When taking down some of these structures the woodwork was generally found to be in perfect condition.

He could support the author to a certain extent in his remarks about the use of breeze. At the same time he could not agree that breeze should never be used. He knew cases where coke breeze has been used with great effect; it was surprising what stresses it could take, and it had a wonderful power of fire-resistance.

Mr. W. A. Green, M.A., etc., emphasised the need of a standard glossary for engineering terms.

As many more gentlemen desired to speak on the subject, the President announced the adjournment of the debate until April 19th.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

STATE MOSQUE AT KUALA KANGSAR, FEDERATED MALAY STATES, ERECTED IN REINFORCED CONCRETE.

As is well known, reinforced concrete lends itself particularly well to the construction of buildings in the Eastern style. We are able to publish in this issue some interesting illustrations of the reinforced concrete State mosque erected at Kuala Kangsar, in Perak.

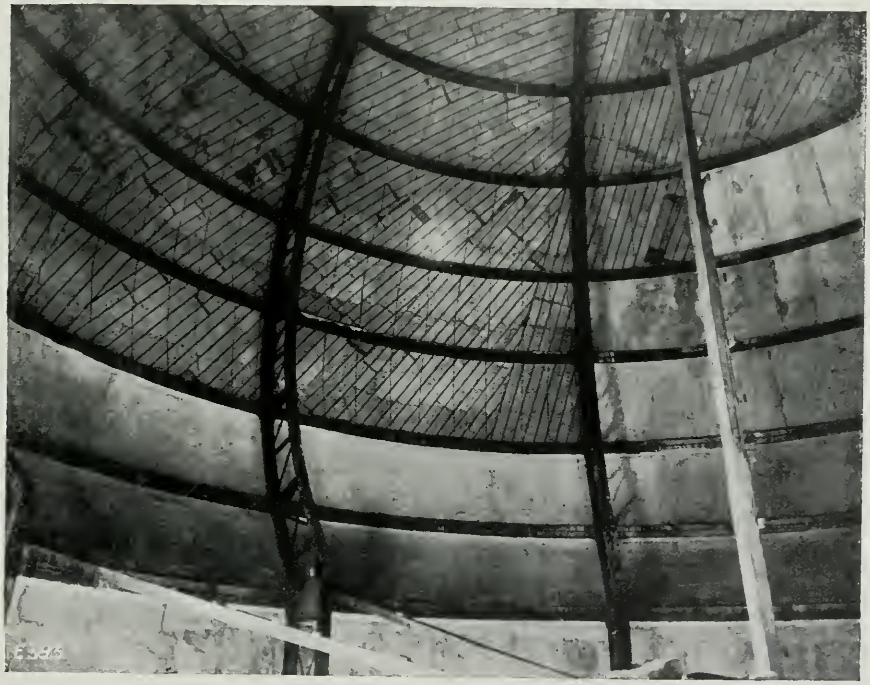


Fig. 1. External Dome, Interior Views.
State Mosque, Kuala Kangsar, F.M.S.

It will be seen from the frontispiece and our illustration, *Fig.* 7, that the building is not yet quite completed. It is practically entirely constructed in reinforced concrete (the Kahn system being adopted), with marble dressings in green and red and cement rendering.

Over the main building and 40 ft. above ground, a large reinforced dome, 60 ft. in diameter, is supported on sixteen reinforced concrete columns, and above this there is

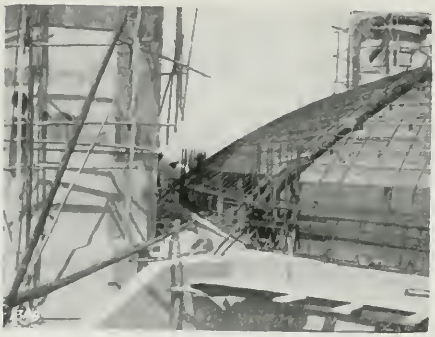


Fig. 2. Internal Dome Reinforcement.

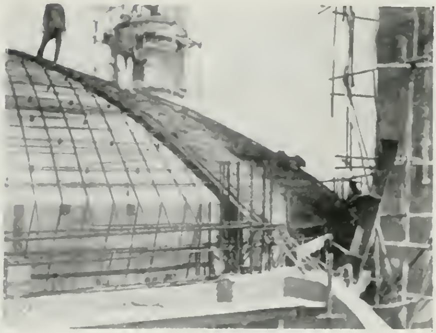


Fig. 3. Dome Reinforcement.

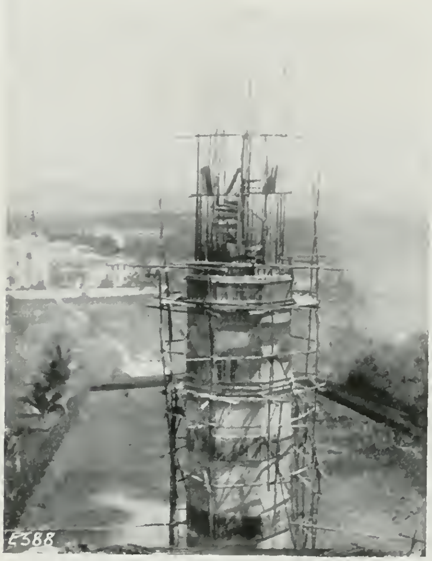


Fig. 4. Prayer Tower Reinforcement.

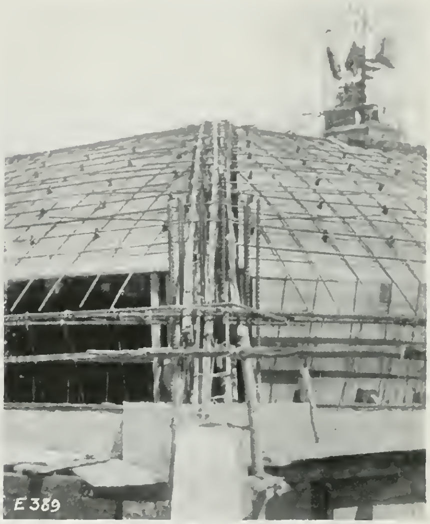


Fig. 5. Rib to Internal Dome.

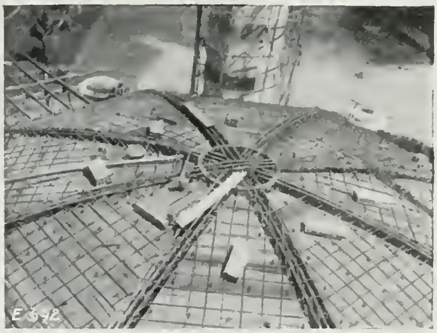


Fig. 6. Dome Reinforcement.

THE STATE MOSQUE, KUALA KANGSAR, F.M.S.

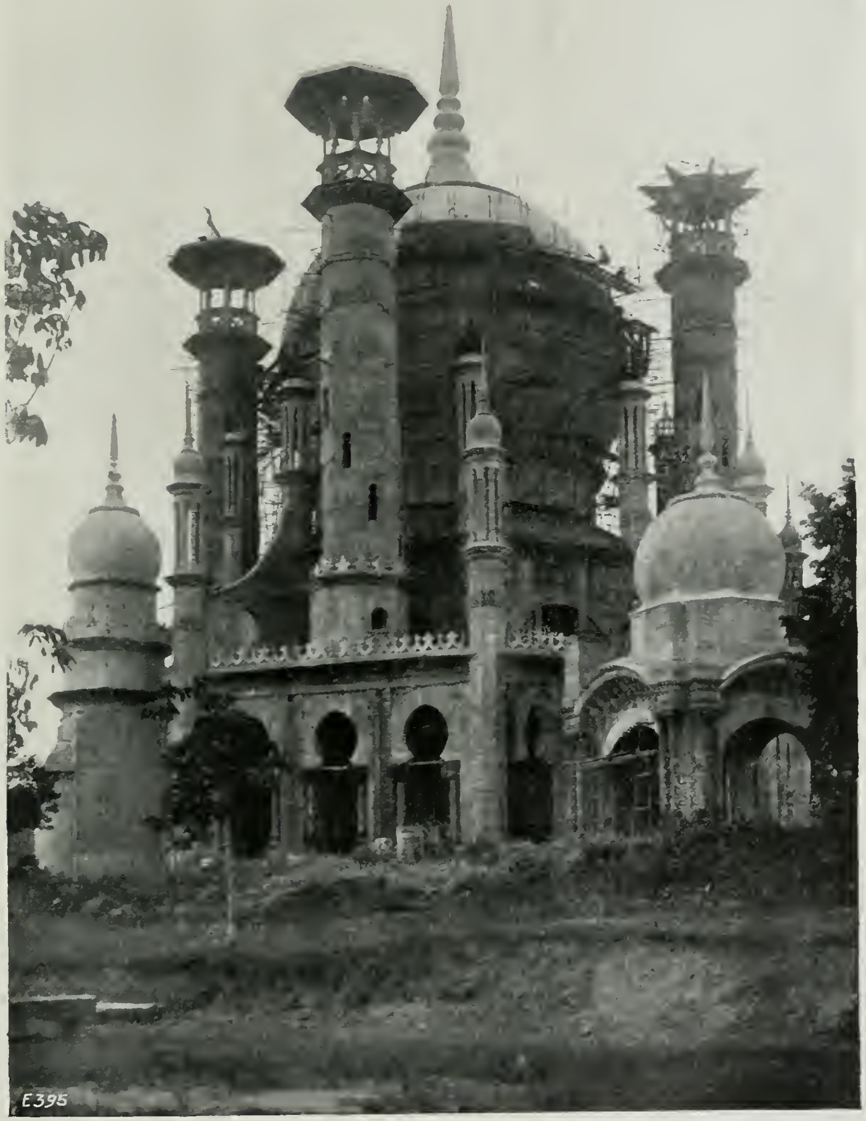


Fig. 7. General View.
STATE MOSQUE, KUALA KANGSAR, F.M.S.

another dome 80 ft. high. There are four minarets 8 ft. in diameter and 125 ft. high, twelve smaller towers about 70 ft. high, and several domes over porches, bathing tank, and elsewhere.

The building is being erected by the Government of the Federated Malay States, and we are indebted to Mr. Geo. E. Kesteven (acting for the Government architect) for our illustrations. The United Engineers Co., of Singapore, carried out the steelwork reinforcement on the Kahn system, as mentioned above.

REINFORCED CONCRETE COAL BUNKERS FOR THE COPPEE COMPANY, LTD.

Reinforced concrete has found one of its principal applications in the construction of coal bunkers, and the work which we are about to describe shows a structure of this nature which has been completed and in use for over eighteen months. Elevated coal bunkers of this description were usually, until the introduction of reinforced concrete, erected in steelwork with brick panels or sheet iron riveted and bolted together. It is obvious, however, that the monolithic nature of reinforced concrete renders it more suitable than steel construction for this particular kind of work, both as far as strength and economy are concerned.

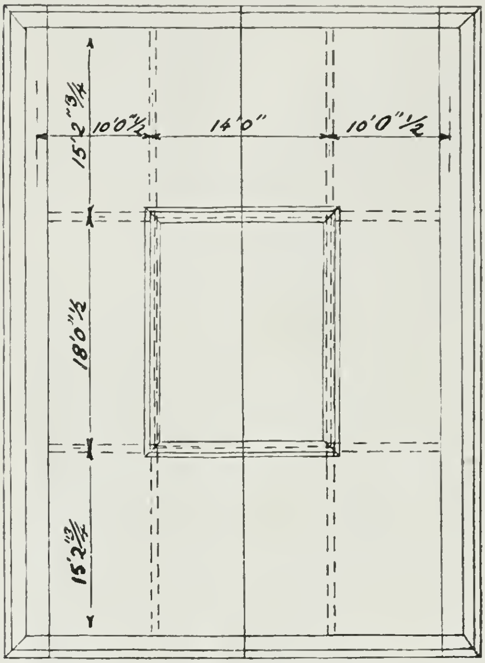


Fig. 1. Roof Plan, showing Roof.
Reinforced Concrete Coal Bunkers at Coedely, South Wales.

The acid fumes which are always found in coke ovens and chemical works have a very deleterious effect on steel construction, whereas they have no effect whatever on reinforced concrete. From the point of view of upkeep alone, therefore, the latter presents great advantages.

The photographic illustration which we reproduce shows an elevated bunker containing 1,000 tons of washed and crushed coal, constructed on the "Coignet System" for the Coppee Company (Great Britain), Ltd., of King's House, Kingsway, London, at Coedely, South Wales. This bunker is fitted with an elevator for raising the washed and crushed coal from the 75 ton per hour Coppee Washery. It is also provided with a conveyer for feeding the electric coal-stamping station in connection with two batteries of Coppee regenerative by-product coke ovens, which are erected on either side of the bunker; arrangements are also made at a lower level so that the coal can be charged in dandies for hand filling of the ovens when this coal-stamping plant is temporarily disabled.

The total height of the bunkers, measured from the foundations to the highest point of the roof, is no less than 109 ft. It will be seen, therefore, that the question of wind pressure on a structure of this height is one of the difficulties which had to be contended with, especially on account of the large wall area exposed at a great height above the ground. Reinforced concrete, however, on account of its dead weight, together with its monolithic nature, offers a considerable resistance to wind pressure.

It will be seen from the accompanying illustration that the work is composed of a working platform supported by six pillars 32 ft. 6 in. high from the foundations. The four central pillars have scantlings of 40 in by 40 in. at the base, and the four corner pillars have scantlings of 29 in. by 29 in. at the base. This working platform is cantilevered at each end over a distance of 15 ft. 9 in.

The main body of the bunkers is also supported by the continuation of the pillars, which extend right up to the roof. From a height of 9 ft. 6 in. above the platform,

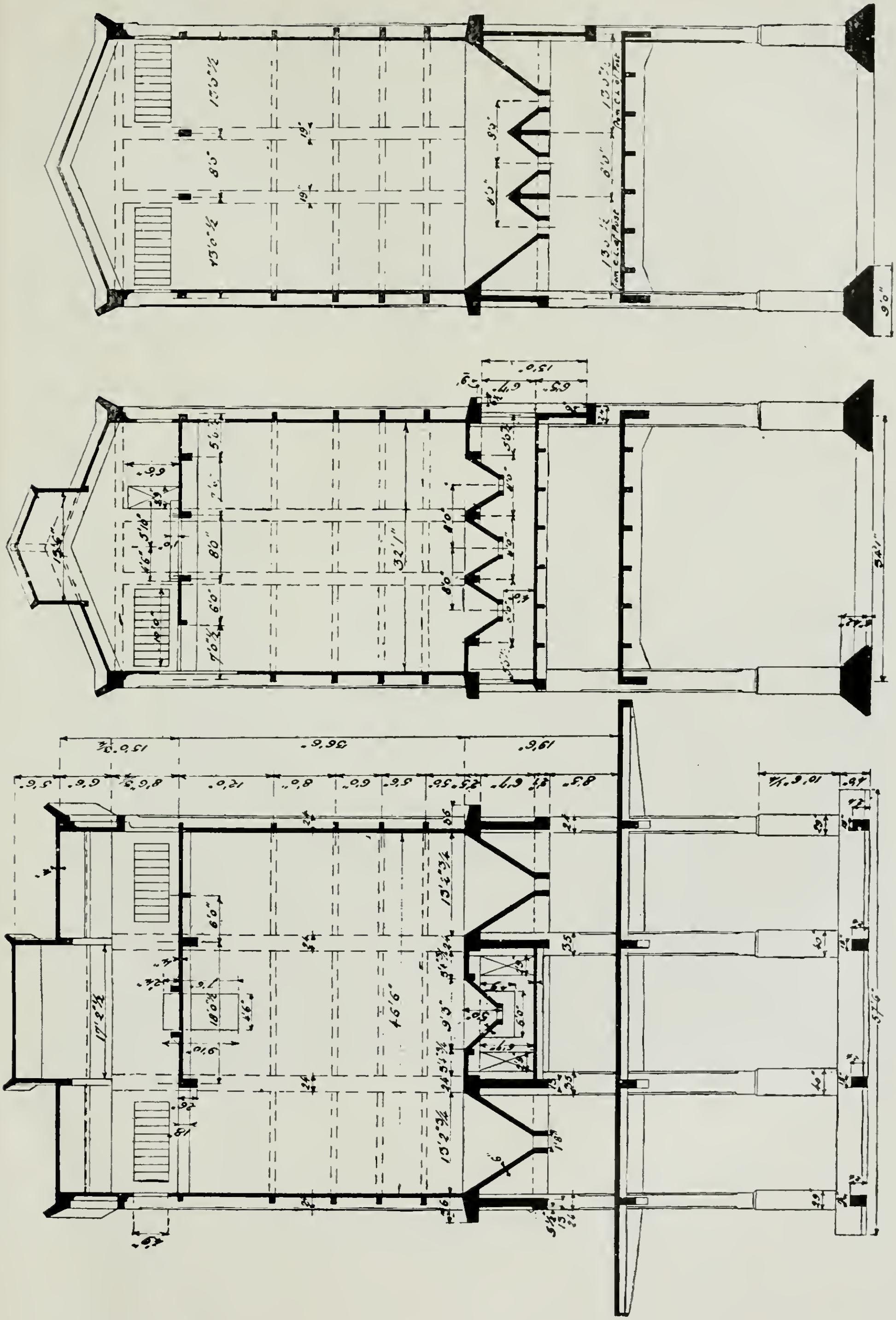


Fig. 2. Sections.
Reinforced Concrete Coal Bunkers at Coedely, South Wales.

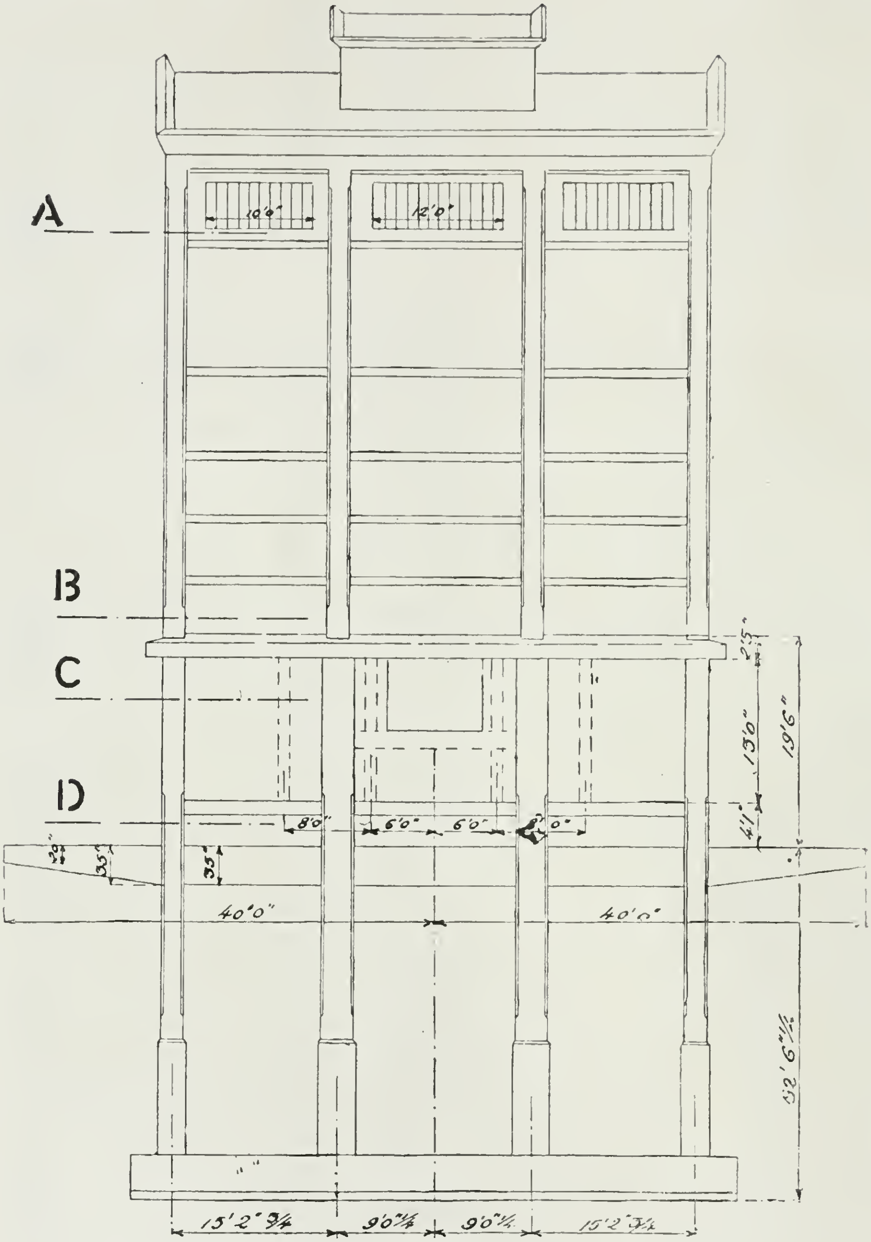


Fig. 3. Elevation.
Reinforced Concrete Coal Bunkers at Coedely, South Wales.

however, these pillars are calculated as vertical beams supporting horizontal ribs upon which the pressure of the panels is distributed. These vertical beams are fixed into large horizontal beams at the hopper level, and at the top floor level they are tied into the beams supporting the floor.

The hoppers, nine in number, are of irregular shape and supported by means of a framework of principal and secondary beams. The principal beams, of which there are four, run transversely with a span of about 34 ft. between the pillars. These beams have a height of about 11 ft. and a thickness of only 13 in. The panels of the hoppers are 6 in. in thickness, and the vertical walls between the ribs are only 4½ in. thick.

The whole of the reinforcement throughout the structure is composed of round bars of mild steel varying between $\frac{3}{16}$ in. and not more than 1½ in. in diameter.

Messrs. Edmond Coignet, Ltd., of 20, Victoria Street, Westminster, were responsible for the preparation of the working drawings and general supervision of the work, which was carried out by Messrs. Watt Bros., contractors, of Cardiff, who have had a very considerable experience in erecting works on the "Coignet System" for the past nine or ten years.

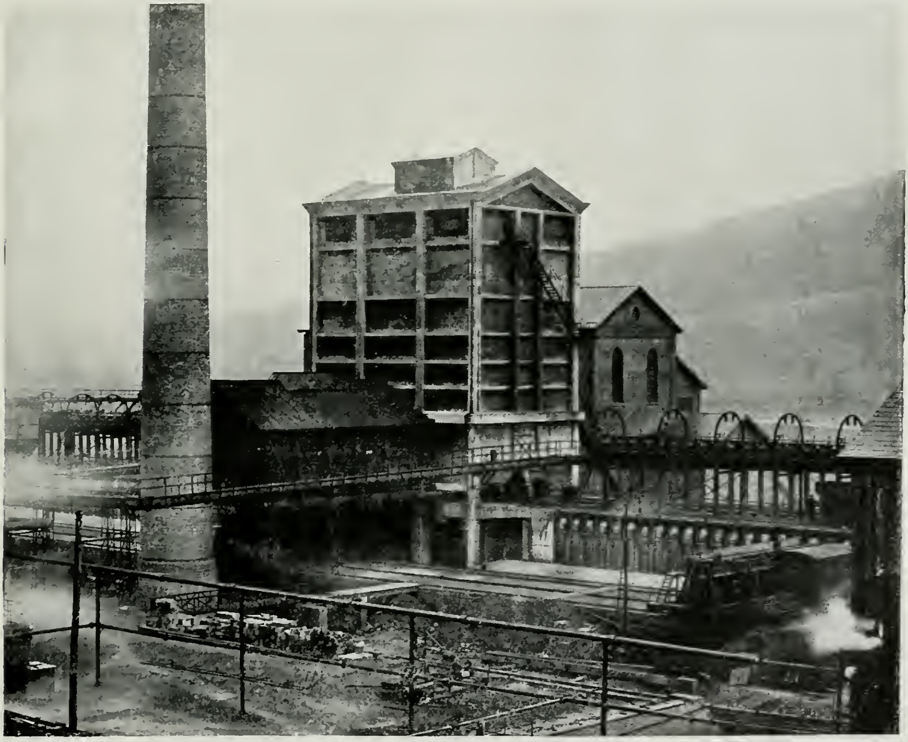
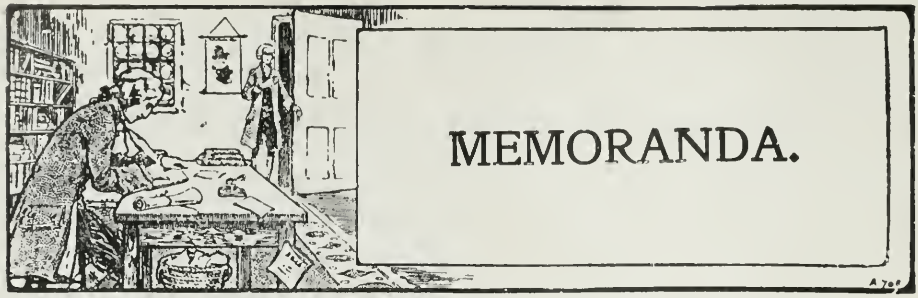


Fig. 4 General View.
REINFORCED CONCRETE COAL BUNKERS AT COEDELY, SOUTH WALES.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Ministry of Munitions.—*High Speed Steel Scrap.*—The Ministry of Munitions forward the following for publication: Arrangements have been made by the Ministry of Munitions whereby the makers of high speed steel will take back all scrap, short ends, etc., at uniform prices. The prices which have been fixed are 5d. per lb. for turnings, 6d. per lb. for bar ends (delivered steelmakers' works).

All material of this kind should be returned as far as possible to the manufacturer who supplied the original steel. In cases where this is not possible, owing to supplies being obtained from a number of manufacturers, the scrap should be returned in proportion to the quantity of steel which was originally received.

The scrap must be packed in convenient sized barrels, or other suitable cases, and should be free from all foreign substance, *and particularly other kinds of steel.* Turnings should be returned as soon as a reasonable quantity can be got together and not kept until rusted solid; such scrap is practically worthless.

Under the regulations published in the *London Gazette* dated March 3rd, as 30 B. of the Defence of the Realm Regulations, it is illegal to dispose of high speed steel through any but authorised channels, and users are therefore advised that the above arrangement should be carried out in every case.—(*Serial No. C.* 1575.)

Cottage Building.—The great necessity for more housing accommodation in Sheffield, not only to shelter the thousands of workers who have come into the city since the outbreak of war, but to provide for the working classes generally, is emphasised by the details which are to be laid before the Sheffield City Council.

The Wincobank scheme for the housing of additional workers has received the further consideration of the Estates Emergency Sub-Committee, and the City Council are to be recommended to make application to the Local Government Board for their sanction to the borrowing of the sum of £69,200 for the purpose of erecting 261 houses on the High Wincobank Estate, in accordance with the scheme approved by the Government authorities.

1. The department concerned has agreed to contribute 20 per cent. of the total cost of the proposed buildings, including the cost of streets and sewers, such total cost being estimated at £86,500—namely, £75,000 for buildings and £11,500 for streets and sewers.

2. It is agreed that the cost of the scheme, less the Government's contribution of 20 per cent. as aforesaid, will be advanced by the Government to the Corporation as and when payments in respect thereof shall fall due, and that the amounts so advanced will be repaid by the Corporation with interest at the rate of 4½ per cent. per annum on the annuity principle, over a period of sixty years in respect of the buildings and twenty-two years in respect of streets and sewers.

3. The houses shall during the period of the war be available for munition workers employed at the national factories in Sheffield or at other works engaged in the manufacture of steelwork, and such workers shall during the same period have prior claim to occupy the houses as tenants and lodgers.

4. The houses shall be completed fit for occupation as to 120 in three months after January 17th last, as to eighty additional in four and a half months from the same date, and as to the balance of sixty-one by July 31st, 1916. Provided that if any delay

occurs which is certified by the City Architect to be due to causes outside the control of the Corporation, the contribution of 20 per cent. as aforesaid by the authorities shall not be reduced or withheld on account of such delay.

An interesting Report issued by a Special Committee appointed to consider the building by-laws of the city will also be placed before the Council. The Sheffield Society of Architects and Surveyors, and the Master Builders' Association, and the Corporation officials have made reports to the Committee on the matter, with the result that the Council are to be asked to agree to by-laws being altered for the period of the war and for two years afterwards, in view of the high price of building materials and the increased cost of labour, and with the object of encouraging the building of cottage property in the city.

The Committee point out that they are advised that economies in the building ot cottage property can be made by omitting cellars and substituting pantries and coal-houses on or near the ground-floor level; by the use of reinforced concrete walls in accordance with by-laws; by advantage being taken of by-law relating to the height of rooms, which permits rooms on the first floor to be 7 ft. 6 in. at the eaves; and by the use of asbestos tiles for roof covering instead of slates in accordance with by-laws.

It is further recommended that the Water Committee be requested to reconsider their regulations requiring a ½-in. separate lead water service to be provided in the case of each house having a bath, as the Committee are advised that this service pipe is sufficient for more than one house. The Committee have under their consideration other questions relating to this subject upon which they hope to be in a position to report to the Council at its meeting in April.—*From "The Builder."*

The Royal Albert Hall.—During the last two years a very large amount of money has been spent on this building. In the interests of the public it became necessary some time ago to replace all the wooden parts of the roof by concrete and steel.

Reinforced Concrete Sewers.—Results of tests recently made upon reinforced concrete pipe for sewers by Mr. A. T. Goldbeck, assistant engineer of the Testing Laboratory, Bureau of Surveys, Philadelphia :—

1. Reinforced concrete pipe, when properly made and properly cured, is very satisfactory for the construction of sewers.
2. The use of a concrete cradle greatly increases the stiffness of the pipe and raises the load under which initial cracking takes place.
3. For sections of the size tested and for smaller sections the placing of the reinforcing near the inner face throughout the entire circumference seems to be justified.
4. The matter of curing should be very carefully controlled, as much stronger pipe will result if care is taken to keep them thoroughly wet, preferably for a period of two weeks.

Finally, the manufacture of concrete pipe should be much superior to that of ordinary construction. Not only should the quality of the available material be carefully investigated, but density tests should be made in order to combine these materials in such proportions as to produce the densest possible concrete. Density and elastic strength are absolutely necessary for good concrete sewer construction.

Picture Theatre at Grantham.— A new picture theatre has recently been opened at Grantham, and every effort has been made to render the building fire-resisting as far as is possible. All the shutters are automatic in design, and reinforced concrete has been largely used. The builders were Messrs. Rudd, of Grantham.

Keighley. —At a meeting of the Keighley Waterworks Committee, it was suggested by the Engineer and Consulting Engineer that concrete be substituted for clay in case wall of the embankment of the new Lower Laithe Reservoir at an additional cost of £15,000. This was due to the fact that sufficient clay was not obtainable within the specified distance, and this meant an increase of 7½ per cent. to the total cost of the scheme, but there was no question as to which was the better material.

Engineering after the War.—A sub-committee has been appointed by the British Electrical and Allied Manufacturers' Association to concentrate public attention on the increased importance of the whole engineering industry from the point of view of national safety and revenue-earning power when normal conditions are restored. It is the general opinion amongst business men that the greatly augmented output capacity

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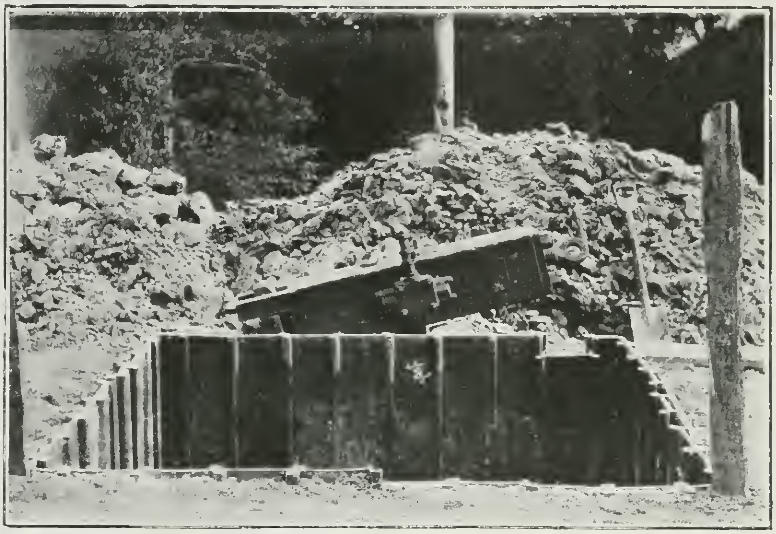

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of British engineering works due to the intensified production of munitions will require extraordinary measures to be taken in regard to collective effort for obtaining a proportionate increase in Britain's share of the world's trade, and at the same time some special consideration in any reform of national and imperial commercial policy.

The country will possess, on the return of peace conditions, an engineering industry of enormously greater and more efficient productive capacity, and it is believed that the intelligent utilisation of these sources of wealth may prove the most important of all factors in solving the problem of rapid restoration of prosperity, by affording a continuance of remunerative employment for our large army of skilled and unskilled munition workers, and for an important proportion of the men released from military service.

The action to be taken by this Association has no special reference to the particular interests of any section of the industry, but will be directed to further the common interests of all British engineering manufacturers. The Secretary of the Association will supply further information to all who are in sympathy.

Leaky Seams and Rivets in Marine Boilers.— In an article on the preservation of marine boilers in the *Mechanical World*, Mr. T. J. Rogers mentions that " One of the most common sources of external corrosion are exposure to leakage from joints, tubes, or fittings. . . . Leaky seams and rivets should be caulked at the earliest opportunity; in some cases in old boilers where the seam is beyond caulking and is on or near the shell bottom, the application of a dose of cement will often greatly check or stop it. Take about equal parts of Portland cement and fresh sharp sand, mixing with fresh water to the consistency of mortar, and apply to the faulty seam from the inside of the boiler. Wherever the cement is to be applied the metal should first be thoroughly cleaned with lye to remove any grease or sediment."

Reinforced Concrete and Explosions.— A dynamite explosion which occurred recently in the factory of Messrs. Peabody, of Walkerville, Canada, again demonstrated the resisting power of reinforced concrete. The explosion was a very violent one, and the lateral effect of it was such as completely to blow out about 10 ft. to 15 ft. of the brick retaining wall, scattering it over a space of 90 ft. from the wall. But the owners report that, apart from the destruction of the concrete slab under which the charge was placed, there was not one particle of concrete so much as chipped in any part of the building.

Reinforced Concrete in the Urals.—We learn from the daily Press that the Ural district is likely to be in the future a very extensive market for cheap cement, especially in view of its employment in the making of reinforced concrete, which is now beginning to be extensively adopted both in private buildings and in various works and factories.

A Method for Testing Hollow Concrete Blocks.— A note in the November issue of *I Materiali da Costruzione* refers to the method of testing hollow concrete blocks. The mixture should not be poorer than 1 : 3 : 4, and the surface should be trowelled to increase the compactness. If the breaking load of crushing strength of the concrete be 70kg./cm.^{2}, a safe load of 7-8 kg./cm.^{2} may be assumed. In walls which carry a load, the cavity of the blocks should not be greater than $\frac{1}{3}$ of the whole wall for a house of two stories, $\frac{1}{4}$ for one of four stories, or $\frac{1}{5}$ for one of five stories. The thickness of the partition between two neighbouring cavities should not be less than $\frac{1}{4}$ of the height of that partition. Laboratory tests should be made with blocks not more than sixty days old. The crushing strength may be more than 70, and must not fall below 49 kg./cm^2. Not more than 22 per cent. of water must be absorbed by the dry block, and this figure is not usually more than 15 per cent.

The crushing strength of the block is expressed in terms of the total area, without deducting the area of the cavity. For the absorption tests, the block is immersed in water to a depth of 13mm., and weighed after 30 minutes, 4 hours, and 48 hours, a new test of the crushing strength being made after 48 hours. Freezing tests are made in a freezing mixture, immersing ten times alternately in the mixture for twelve hours and in ordinary water for four hours, after which the crushing strength is again determined.

Foundations for the "Astor Bar," Amsterdam.—The February number of the Dutch periodical, *Gewapend Beton*, contains a note on the special form of foundations employed in the construction of the "Astor Bar" in Amsterdam. It was necessary to construct a cellar without disturbing the upper floors of the existing building. Drawings are given to illustrate the method adopted, which consists in making the walls of the cellar of reinforced concrete, carrying brackets on which the old walls are supported. The floor of the cellar is also reinforced, and is 30cm. thick. The monolithic construction ensures a stable building.

The same issue contains an article on the resistance of concrete to water, by J. A. van der Kloes, and one by Capt. P. W. Scharroo, in which the application of reinforced concrete in the construction of fortifications is described and illustrated. The structures, of which drawings are given, are permanent forts having concrete protection for guns.

ERRATUM.

In reporting on the discussion following the reading of Mr. Chas. F. Marsh's Paper before the Concrete Institute, entitled "Reinforced Concrete as applied to Water Works Construction," the following printer's errors occurred on p. 147:—

At the end of the first line the word "cement" should be "stone."

In the last paragraph but one, second line, the word "advisable" should be "inadvisable."

In the last paragraph, first line, the word "decrease" should be "increase."

PERSONAL.

Mr. Alfred Robinson, who has been engaged for the past nine years as London manager for Messrs. L. G. Mouchel and Partners (Hennebique System of Reinforced Concrete), has resigned from that firm and has joined the staff of the Trussed Concrete Steel Co., Ltd. (Kahn System of Reinforced Concrete).

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CONCRETE THE MONEY SAVER

CONCRETE FENCE POSTS.

Under this heading we propose, from time to time, to give particulars and illustrations showing how concrete can be economically used by the small builder, the farmer, the gardener, etc. Below will be found some particulars as to the making of concrete fence posts, and whilst we have given illustrations explaining the text, we have added a number of photographs of work actually carried out.—ED.

Introduction.— Experience has shown that as a material for the construction of fence posts concrete has many advantages (and practically only one disadvantage) over wooden posts, and it is far superior to all types of timber posts. In the first place, the cost of concrete posts at the present time is less than the cheapest kinds of wood; but, as these times are abnormal, it is only fair to take as a basis normal times. In ordinary times the cheapest sorts of timber, such as deal, might be slightly cheaper than concrete, but this depends upon the locality, and after three years' service a deal post will have lost one-half to two-thirds of its original strength, whereas concrete grows stronger with age and requires no repairs, for neither fire nor weather injures it. In fact, the rougher the weather the better the concrete becomes. Under ordinary circumstances good concrete posts will last for ever; even if, in the course of years, they should be broken by unusual strains, it is cheaper to replace a post than have to replace an entire fence of decayed wooden posts. If attention is paid to the mixing and also to the aggregate, always ascertaining that the aggregate is free from loam, and that this is always gauged with the same quantity of cement, it will be found that the concrete post will have an attractive appearance, because of its uniformity of colour and size.

Moulds.— Either wooden or metal moulds can be used for line posts. The wooden moulds have all the edges which are exposed to wear faced up with iron, while the metal moulds are composed of steel and cast iron. The moulds are so constructed to enable the posts to be made singly or " batches " or " sets."

Steel Moulds.—It is advisable when buying fencing post moulds to ensure that they are simple in general design and shape, and it is also of great importance to anyone who is undertaking the manufacture of these posts to see that the fastening arrangements are simple, but at the same time efficient, as much time is often lost in operating the moulds.

Wooden Moulds.— Wooden moulds good enough for ordinary demands are very easily made. White pine is the best wood for the purpose, but this is very expensive. Cheaper kinds of wood, which are just as easy to work, may be used. Another very suitable wood is bass or American whitewood. In all cases of wooden moulds the edges require lining up with thin iron plates, so as to protect them from the rammers and also from wear when trowelling off the top.

Moulds for Square Posts.—Moulds for posts that are square, or nearly square, in cross section are simple and easy to make. They are made in three patterns: (1) For posts without taper; (2) for posts with taper on two sides only; and (3) for posts tapering on all four sides. In order to avoid sharp and irregular edges, neater posts are made by laying pieces of angle strips in the bottom corners of the mould, so that when the posts are exposed they show a chamfer; this is done by means of a specially

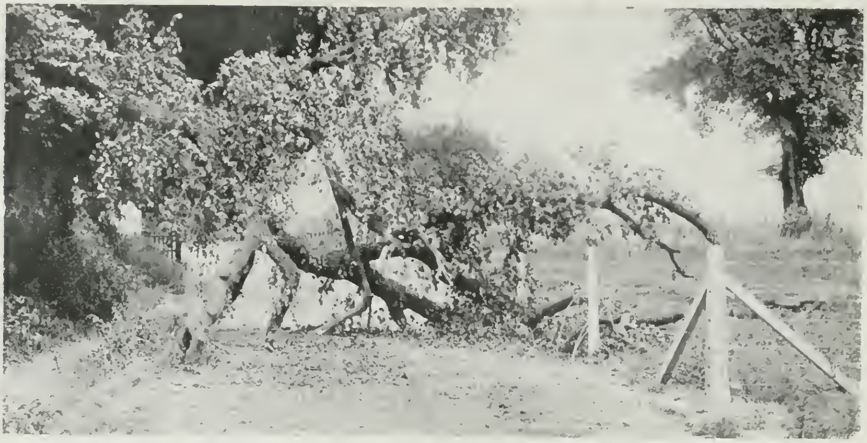


Fig. 1. A striking illustration of the durability of concrete fence posts, showing how the posts remained intact after a storm, although a tree fell across the fencing and broke the wires.

designed trowel or "edger," which levels the top of the post and chamfers the edge at one operation. The size of the angle strips should not be more than $\frac{3}{4}$ in. across the angle or else they will crowd out too much concrete, and thus cause the reinforcement to be located too far within the post to obtain the utmost strength, thus weakening the post. In all ordinary posts the reinforcement should be placed about $\frac{3}{4}$ in. or 1 in. from the outside corners of the posts.

Figs. 2 & 3.

Reinforced Concrete Fence Posts for a large cattle pen. These posts are 4 ft. 8 in. high, 6 in. by 6 in. at top, and 7 in. by 7 in. at base.

Posts without Tapers.—The easiest and cheapest mould to make is the straight mould. Such moulds are merely long boxes made with various schemes, so as to allow the post to be moulded in as simple a manner as possible.

On account of the wood which can be saved and the ease with which "batch" moulds can be filled, straight post moulds are usually made in "batches" or "sets" by constructing several side by side with bottom and end continuous. In some cases just the framework of the mould is made, *i.e.*, the sides and ends of the mould without the bottom. In this instance the posts are made on a wooden floor or, perhaps, upon a concrete floor. If they are made upon a concrete floor paper is first placed on the concrete and the mould put upon it. This will keep the wet concrete, which forms the posts, from sticking to the floor.

Posts Tapering on Two Sides.— Posts tapering on two sides are preferable to straight posts in many respects. A satisfactory size for this style is produced in a mould 4½ in. deep by 6 in. wide at the butt, tapering to 4½ in. by 4½ in. at the top, and 7 ft. long. These posts may be more easily made in a "batch" mould, and are so arranged that the butt of one post lies to the top of the next. This allows for the taper on each and also saves space.

Posts Tapering on All Sides.— Square posts are also made tapering on all four sides. A very satisfactory size of line post may be obtained by making the moulds 5 in. by 5 in. at the base, tapering to 3½ in. by 3½ in. at the top, since all butts are placed at one end of the mould and the tops at the other, so that this arrangement allows for the continuous bottom and ends as mentioned before, but causes the top of the mould to be narrower than the butt end, as the difference in the size of the post at the top and bottom will alter the size of the mould at the top according to the number of posts included in the "batch" mould. The variation in the length of the side boards and of the moulded posts is, however, so slight (hardly a quarter of an inch in the length) that no attention need be paid to it, and all the side boards can be made the same length. The construction of the mould can be easily understood from the illustrations, *Fig.* 5. If holes are required to be cast in any of these posts for the wire to pass through the moulds will have to be constructed as shown in *Fig.* 12. It will be seen that this mould is so constructed that each post lies square with its own centre line. If this is not done the holes through which the wire passes would not be in alignment with each other when erected.

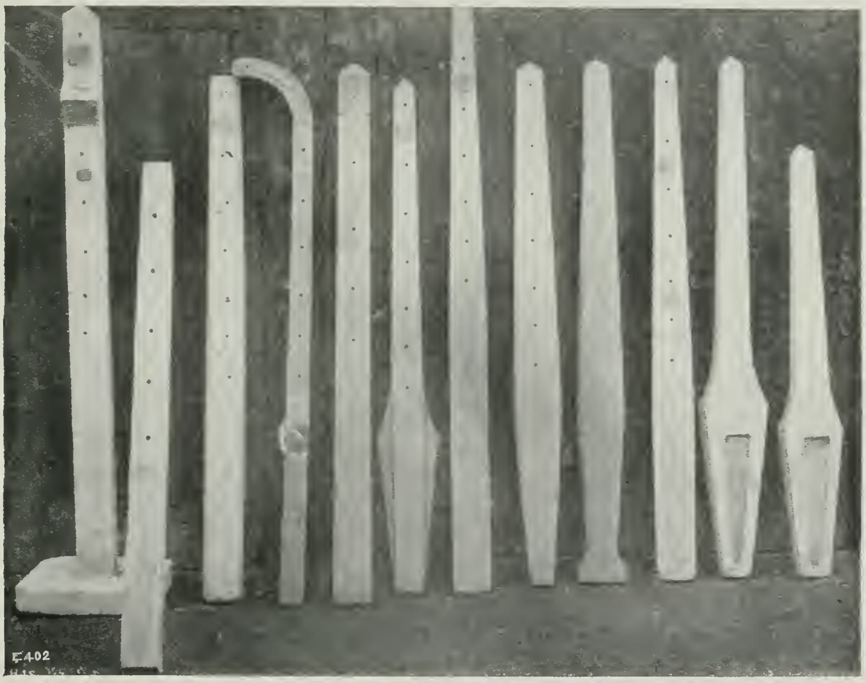
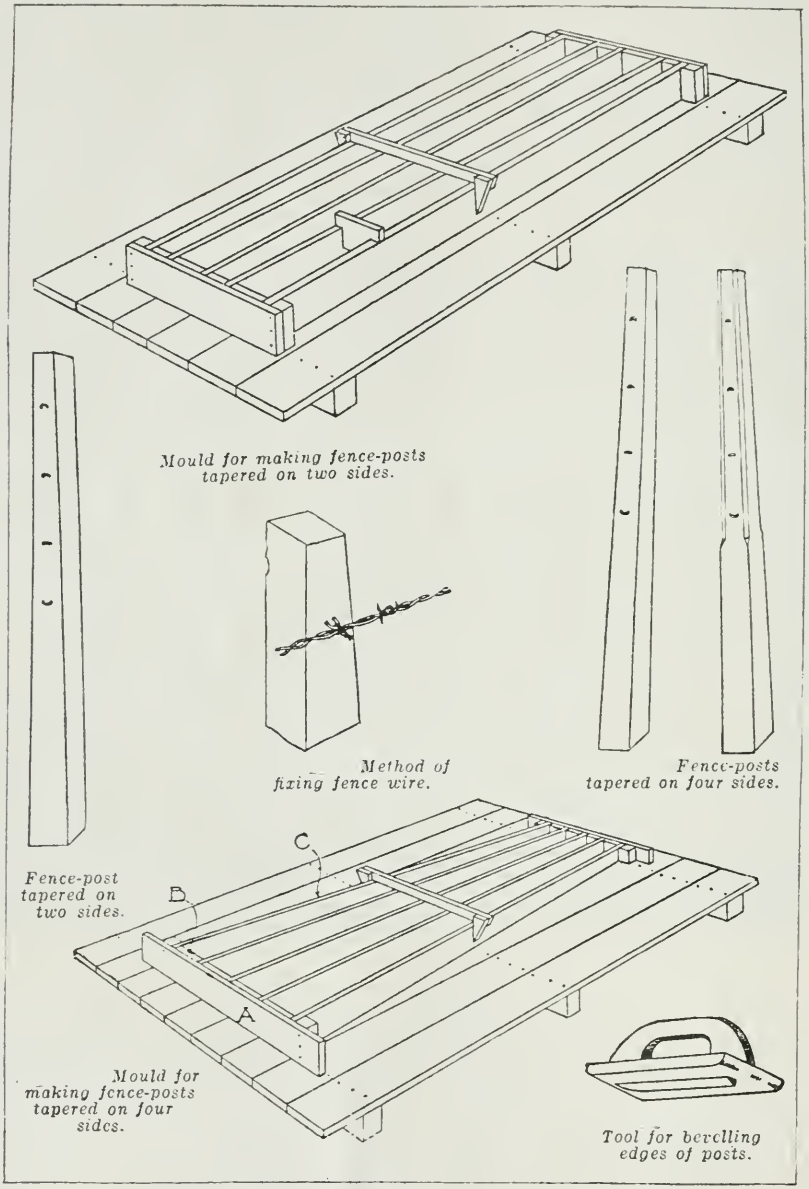


Fig. 4. Reinforced Concrete Fence Posts of Various Designs.

Moulds for Triangular Posts.— Triangular moulds without any taper in their length can easily be constructed in "sets" or "batches." On account of their shape the moulds can be made of 1-in. boards, as at any point the sides can be braced. The illustrations show the end section of three moulds for triangular posts of different sizes. The two boards are hinged together at the ends, and also at three equal points along the sides, by ordinary 3-in. wrought iron strap hinges bent to the shape of the mould and fastened with $\frac{3}{4}$-in. screws.

Sharp corners on a post of this type are objectionable for several reasons, on account of their roughness and sharpness, and it is also a waste of material to make these corners sharp, as no strength is obtained by them, and if they are used for fencing where cattle are allowed to graze the cattle are apt to get cut when rubbing up against them. This undesirable feature is avoided by placing a wooden tongue or strip (marked T) in the bottom of the mould, as shown in the sections, and by making flat or rounding corners at the upper surface, either with a trowel or with an "edger."


Mould for making fence-posts tapered on two sides.

Method of fixing fence wire.

Fence-posts tapered on four sides.

Fence-post tapered on two sides.

Mould for making fence-posts tapered on four sides.

Tool for bevelling edges of posts.

Fig. 5.

Oiling for Moulds.—Concrete has a tendency to stick to steel or wood. In order to obviate this, and to yield a smooth finish to the post, it is customary to give the inside of the mould a thin coating of oil. Soft soap and crude oils, if used sparingly, serve the purpose well, but oils are now made expressly for this purpose, and can be obtained from the Leeds Oil and Grease Co., Ltd., of Leeds. Too much oil will destroy the setting qualities of the cement and will also give the face a rough appearance, having pockmarks all over it.

Reinforcements.—No forms of wooden reinforcements can be recommended. Metal reinforcements have proved themselves in practice to be absolutely unapproachable, but it requires to be designed for the different articles for which it is required. For reinforcing fencing posts round or square rods may be used, but if they are smooth the ends should be bent or looped to prevent slipping in the concrete. For the sake of economy the smallest amount of reinforcement should be used consistent with the strength desired, and this requirement makes it essential that the reinforcement should be placed near the surface (about ¾ in. to 1 in. from the surface). At this point its strength is utilised to the best advantage, and with only sufficient concrete on the

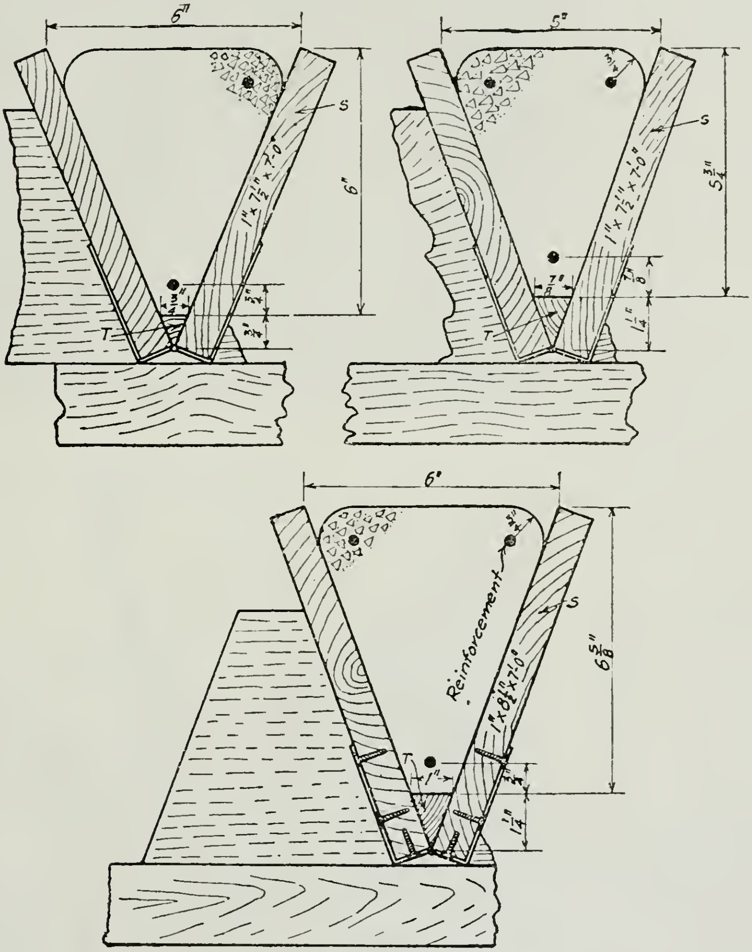


Fig. 6. Moulds for Triangular Posts.

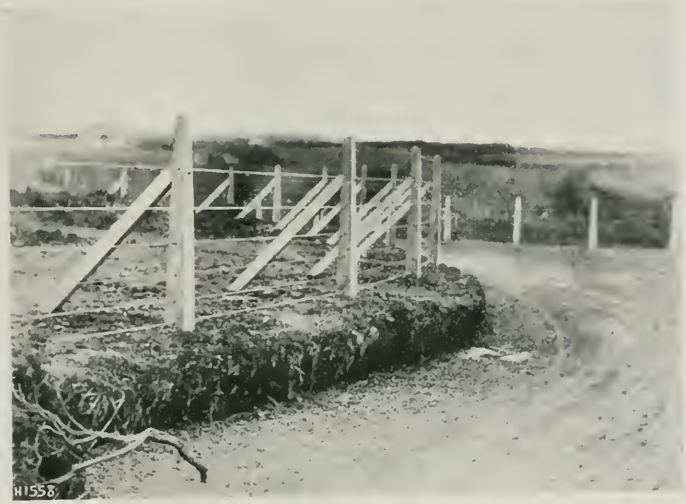
outside of the reinforcing to form a protective covering and also to keep it from breaking out. If kept less than $\frac{3}{4}$ in. from the surface it will be found that when the strain comes on these posts the reinforcement will break out. If a reinforcing rod is placed in each corner of the post, at $\frac{3}{4}$ in. to 1 in. from each corner, it will be seen that this is probably the most efficient arrangement. The rods for reinforcing posts such as are shown in the illustrations should not be less than $\frac{1}{4}$ in. dia. rod or $\frac{1}{4}$ in. sq. rod. There are a number of good reinforcing bars on the market to which the concrete will cling and adhere, and will not break away when the posts have to withstand strains. Metal slightly rusted is as good if not better than metal that is not rusted.

The Midland and Great Northern Joint Railway, who have hundreds of miles of concrete fence posts on their system, always use four $\frac{1}{4}$-in. rods, and these are all bound together at their right centres with wire, so that all four rods give support to each other.

Attaching Wire to Posts.—The illustration (*Fig.* 13) shows how to attach the fence wire to concrete posts. Various methods are in use, but the one that has obtained universal favour is the method of threading the wire through holes cast in the posts and the wire strained tight.

Sometimes the method is adopted of casting of long staples in the post, and to these staples wire is attached by means of galvanised binding wire. The staples must either be bent or twisted at the ends to prevent extraction. Another method which is coming more into use is that of casting nail jackets in the posts, which enable staples or nails to be driven

Figs. 7 & 8. Reinforced Concrete Fence Posts, Swanscombe.



These fence posts have been erected on the new Fishguard route, which is 2,600 feet in length.

Fig. 9.

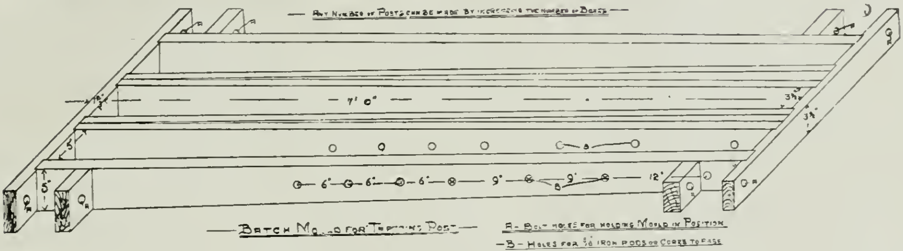
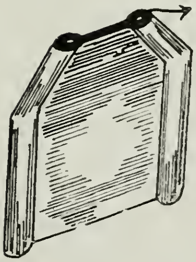

Any Number of Posts can be made by increasing the number of Boards
7' 0"
5"
5"
3½"
3½"
6"
6"
6"
9"
9"
12"
A
B
Batch Mould for Tapering Post
A – Bolt holes for holding Mould in Position
B – Holes for 5/8 iron rods or cores to pass through for holes for wire

Fig. 10.



This Face exposed, other part embedded in the Concrete.

Fig. 11. Nail Jacket.

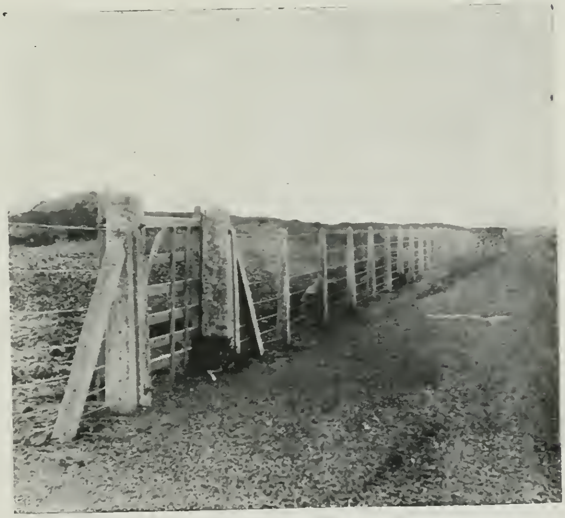


Fig. 12. Reinforced Concrete Fence Posts at Dinas Way, Haverfordwest.

in, and when in they cannot be withdrawn, *Fig.* 11 shows the nail jacket, and as nearly the whole of it is embedded in the concrete it cannot rust. This allows barbed wire to be fixed to concrete posts cheaply and effectively. These are made of steel and are pressed to the shape.

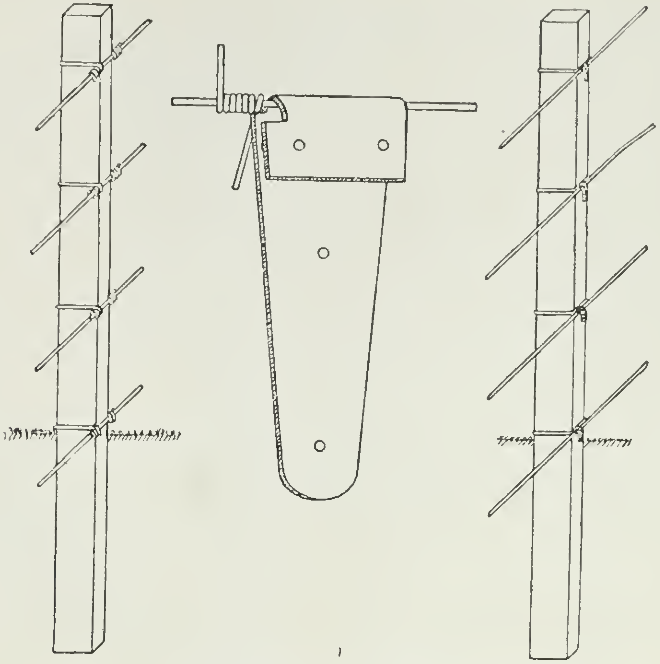
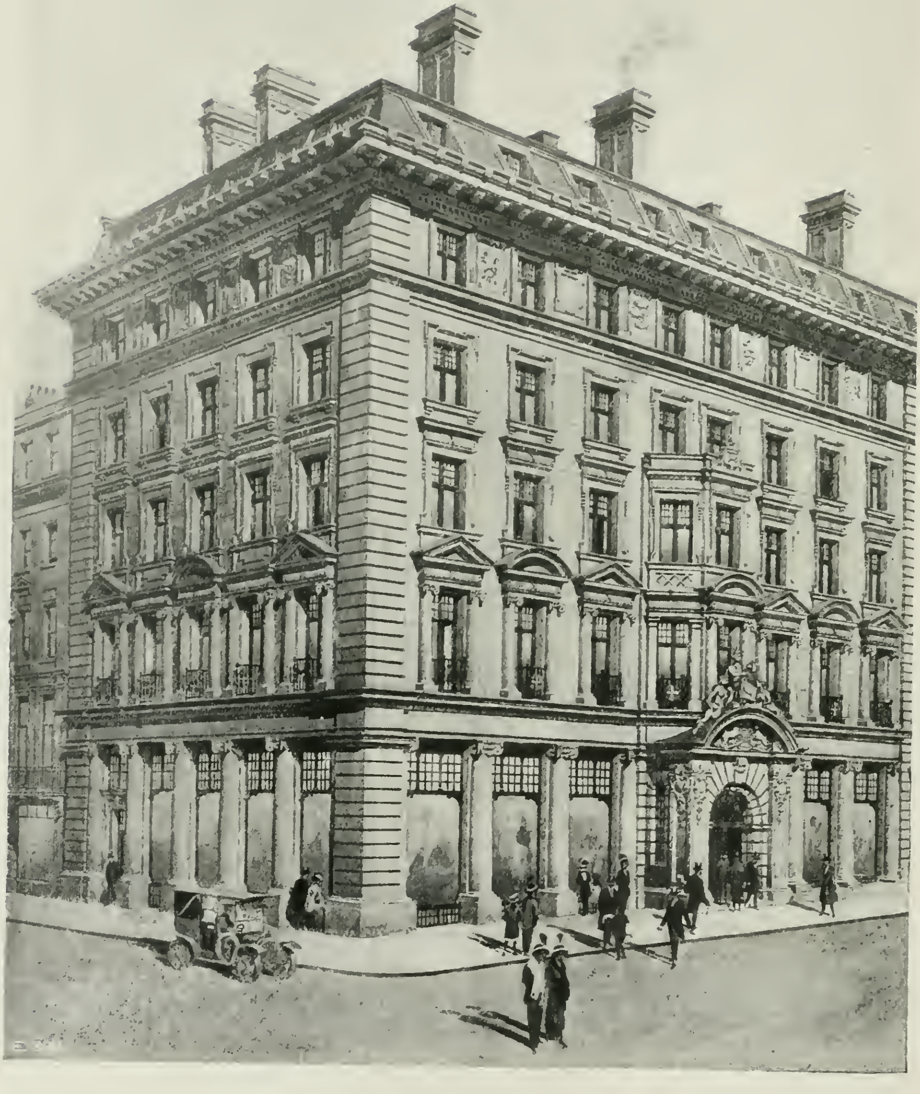


Fig. 13. *Method of attaching fence wire to concrete posts*

In the next supplement we shall deal with the mixing of the concrete, the moulding and curing of the posts, also the erection of the fence.



Part Elevation.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.
(See page 225.)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XI., No. 5. LONDON, MAY, 1916.

EDITORIAL NOTES.

RESEARCHES ON REINFORCED CONCRETE.

WE have always advocated research work in connection with reinforced concrete, and from time to time have impressed upon our readers the great value of researches in all branches of industry in the country. It is therefore with much pleasure that we commence a series of articles in this issue, by Mr. Oscar Faber, dealing with the subject, and there is no doubt that they will be read with great interest. Rational and empirical formulæ both have great value, but the former are generally used by designers who have not had the slightest opportunity of experimental work and consequently do not realise the difference between theory and practice. All rational formulæ are based on certain assumptions, and if these assumptions are not in accordance with actual facts it is obvious that the theoretical conditions will not agree with practical results. The tests conducted by the author, and described by him in the articles, are of particular interest, as they illustrate in a marked degree the variation beween theory and practice. All the formulæ considered by him are claimed as "rational," and it means that these are investigated practically, and, if satisfactory, they become both rational and empirical. As a general rule, empirical formulæ are unsatisfactory, because they are based on experiments conducted by individuals and not on what might be termed national research work, and in consequence no guarantee is provided that the experiments are exhaustive or carried out under the proper conditions. It is calling for a good deal of faith on the part of the designer if he is asked to accept an empirical formula which is based on the results of one series of experiments only and not backed by theoretical and reasoning which he can follow and approve.

It should be realised that research work is of the highest importance, and it is a national question which must be taken up seriously by the Government and either conducted by them or supported morally and financially. We have a scientific material in reinforced concrete, and its use is becoming daily more universal; and yet, with the exception of a few experiments conducted by the more progressive institutions and engineers, no attempt has been made to take up research work which would clear up questions of the utmost importance. Our policy is progress, and unless modern construction is properly assisted by the application of scientific knowledge it will never make the progress that it should. Ambition is a fine thing, and there is no reason why it should be confined to individuals. The State should also be ambitious with regard to progress in science and all matters relating to the general welfare and uplifting of its subjects; and to compete successfully in the markets of the world they must be supplied with reliable information as to the results and behaviour of materials obtained by the application of research.

In other countries research work is encouraged and substantial grants are made, which allow the work to be carried on. Why is the same method not adopted in this country? This war has done a great deal in opening the eyes of the people in Great Britain as to our shortcomings in the scientific world, and there is every hope of steps being taken which will enable us to regain some of the lost ground.

The experiments carried out by Mr. Oscar Faber to show the moment of resistance of doubly reinforced beams form a typical instance of the value of research work. Here we have a case in which the regulations of the London County Council allow a method of calculation which the author of these articles agrees is economical, but he doubts if it can be justified, and on the results of his experiments his opinion appears to be correct. Many designers work according to the revised regulations for compressive reinforcement which enable them to economise in steel, and they cannot be blamed for this, as the cost of the work is increased considerably when the stress in the steel is limited to " m " times the stress in the concrete at the same distance from the neutral axis. If, however, the economical method of design cannot be supported by results obtained from actual experiments, then it is obviously necessary that engineers should know this. There are many similar points in reinforced concrete construction which require proper investigation, and it would be comparatively easy to put forward a programme to cover the immediate needs of the engineering profession. It is a poor policy to wait until the war is over before organising research work, as there will be a tremendous amount of important designing to be done and there will be competition all over the world amongst engineers. The time may be short, as we all hope it will be; but if a start is made at once a certain amount of work would be done, and in any case an organisation would exist which could be applied to the most pressing problems. A thorough investigation of reinforced concrete in a practical and scientific manner is not possible to the individual engineer, and it is only through a proper combination of the most eminent men, together with sufficient funds, that the matter can be properly dealt with. The foresight and energy of the engineer who does undertake experimental work in the manner described by Mr. Oscar Faber cannot be too highly commended, as it confers benefit on all those who follow his work, but at the same time it is insufficient to meet our present needs and the proper appreciation of the engineering profession would be best expressed by supporting him in a demand for a thorough system of research work, which would make the scientific contribution of this country second to none. Leading engineers do not entirely agree on many points which might almost be termed elementary in character, and yet the ways and means of settling these questions are neglected. Such a state of affairs should not be allowed to continue.

THE BRITISH COLUMBIA BUILDING, REGENT ST., S.W.

The building here described is mainly a steel frame building, reinforced concrete entering only into the construction of the floors.—ED.

This important building has recently been completed for the Government of British Columbia, and occupies a site 100 ft. by 57 ft. at the corner of Regent Street and Charles Street, S.W. It will provide office accommodation for the Agent-General for the Colony in London and also a large Exhibition Hall where the products of the country can be seen and examined. The remainder of the building will be let off for commercial purposes, but is so designed that it can be joined up with the official portion of the building if future needs should warrant such extension.

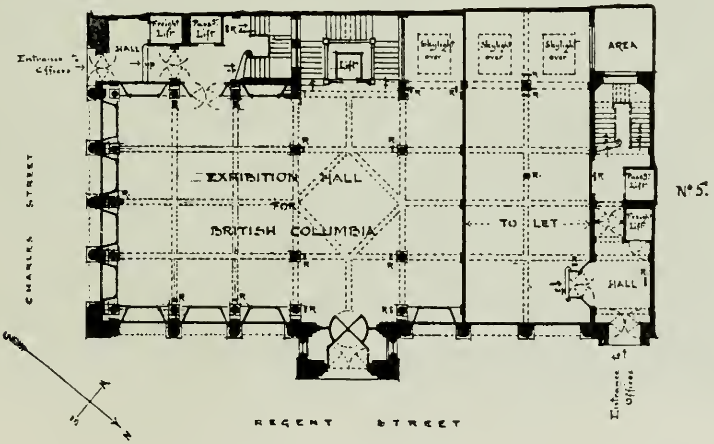


Fig. 1. Ground Floor Plan.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

Exhibits of foodstuffs, minerals, and timbers from the Colony and also specimens of the wild life of its woods and waters are now being arranged in the Exhibition Hall, and the visitor will learn that the land offers opportunity for all branches of commercial life as well as the possibilities of good sport, from big game hunting to fishing. It may be stated that the trade of British Columbia is greater per head of the population than that of any other country, and this exhibition will go far to give information as to the possibilities of success to many men who after the open air life of the Army will be loath to return to their previous office pursuits.

The chief timbers of the Colony are cedar, Douglas fir, hemlock, and maple, and examples of these woods in all stages of finish can be seen in the exhibition and in the building; for materials from the Colony have been used in some of the finishings, and, but for the war, would have been employed to a much greater extent.

The building has been erected under the 1894 London Building Act regulations, although, in many respects, it tends towards being a steel framed structure. *Fig.* 1 gives a plan of the ground floor and shows the Exhibition Hall. This hall is 20 ft. high, and a fine staircase of Piastraccia and Tinos marbles leads to the first floor.

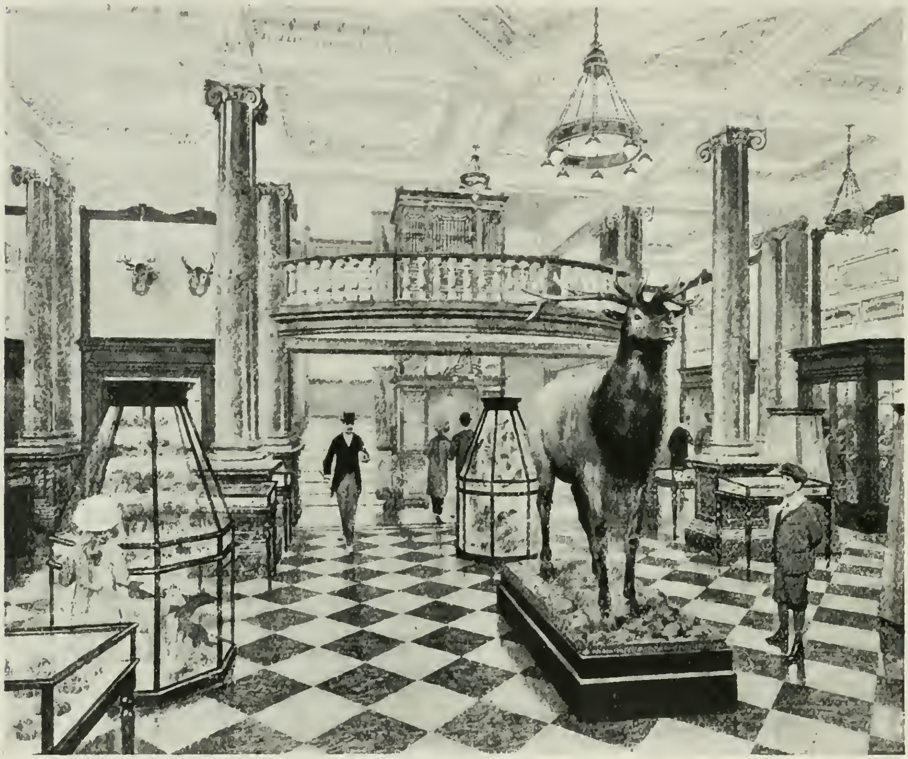


Fig. 2. View of Exhibition Hall, Ground Floor.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

Owing to the height of this hall a balcony is introduced, as will be seen from *Fig.* 2. The dado and balustrade to this staircase are of Swedish green, and the newels and handrail of Tinos marble, and in the well of the stairs runs a passenger lift surrounded with a wrought iron enclosure. *Fig.* 4 gives a plan of the first floor, on which are the official offices of the Colony. The remainder of the building, except for a part of the basement, is left for tenants, and is served by a staircase and lift at Regent Street office entrance and also at Charles Street entrance.

Turning now to the construction, the whole building is erected so that dampness is eliminated as far as possible, and a layer of asphalte on the outside of walls below ground and under the basement floor virtually forms a tank in which the building stands. The basement floor is again covered with asphalte as a further precaution.

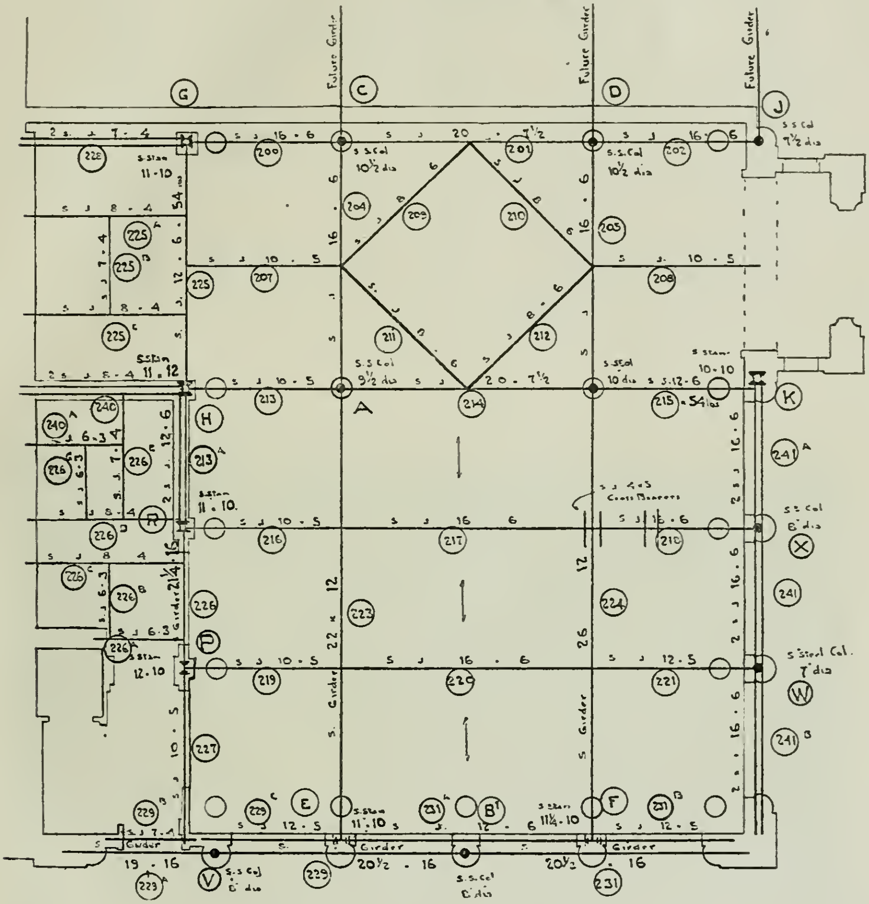


Fig. 3. Ground Floor Plan. Steel Details.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

Externally the building is faced with Portland stone to Regent Street and Charles Street, and the design of the façade is very successful. As will be seen from the frontispiece, the hackneyed columns running through several stories are dispensed with and effect is gained from a careful spacing of windows and a very heavy cornice. Carving is used sparingly, but a fine series of sculptured panels representing the industries and products of the Colony and a sculptural group

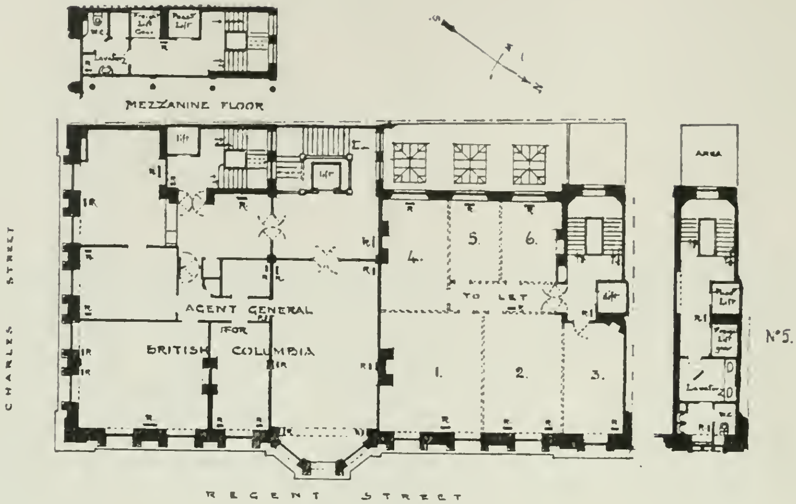


Fig. 4. First Floor Plan.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

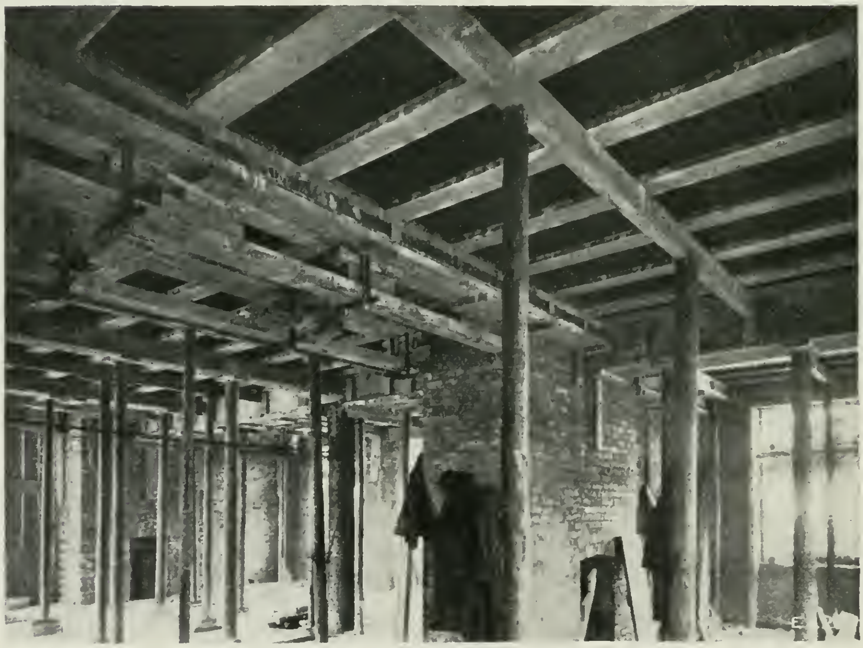


Fig. 5. View of Floretyle Construction.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

over the main entrance, give dignity to the building.

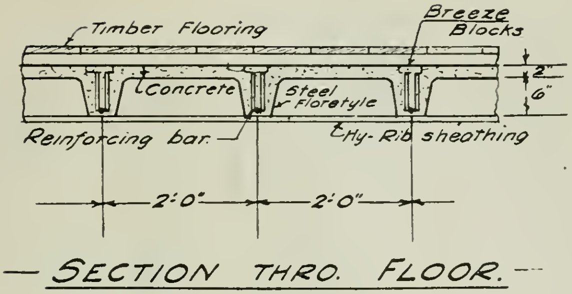


Fig. 6.
The British Columbia Building, Regent Street, S.W.

Fig. 3 shows a plan of the steel framing of the building, by which it will be seen that some of the spans are over 30 ft. These and the intermediate steel beams carry very heavy loads, for the Crown Surveyor insisted upon the chimney stacks being free from the external walls, and few supports were desired in the Exhibition Hall.

As far as possible plain rolled steel joists were used till 20 in. by $7\frac{1}{2}$ in. was reached, but the main beams are built up compound girders, a typical detail of which is seen in *Fig.* 8.

The supporting members of the building are steel stancheons, except on the ground floor, where solid steel columns have been used in most cases. The largest of these columns are in front of the main stairs, and are each $10\frac{1}{2}$ in. diam., and they carry very heavy loads, as the stancheons which they support receive the ends of the main beams. *Figs.* 8 and 9 give details of these columns and the stancheons over and below them, which latter, as will be seen, rest upon cast iron bases.

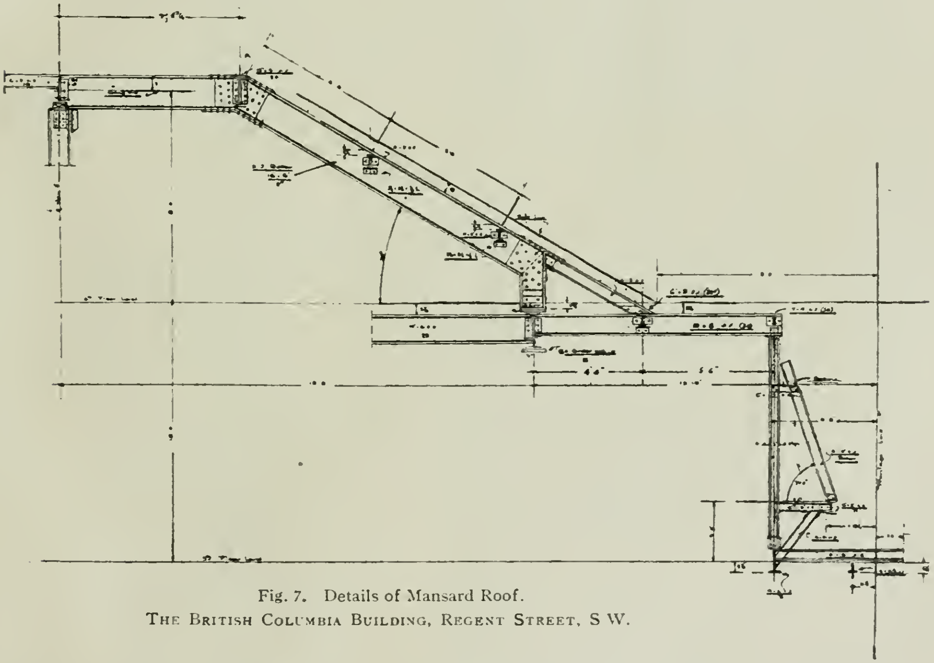


Fig. 7. Details of Mansard Roof.
The British Columbia Building, Regent Street, S.W.

The heavy crowning cornice has already been mentioned, and as the wall

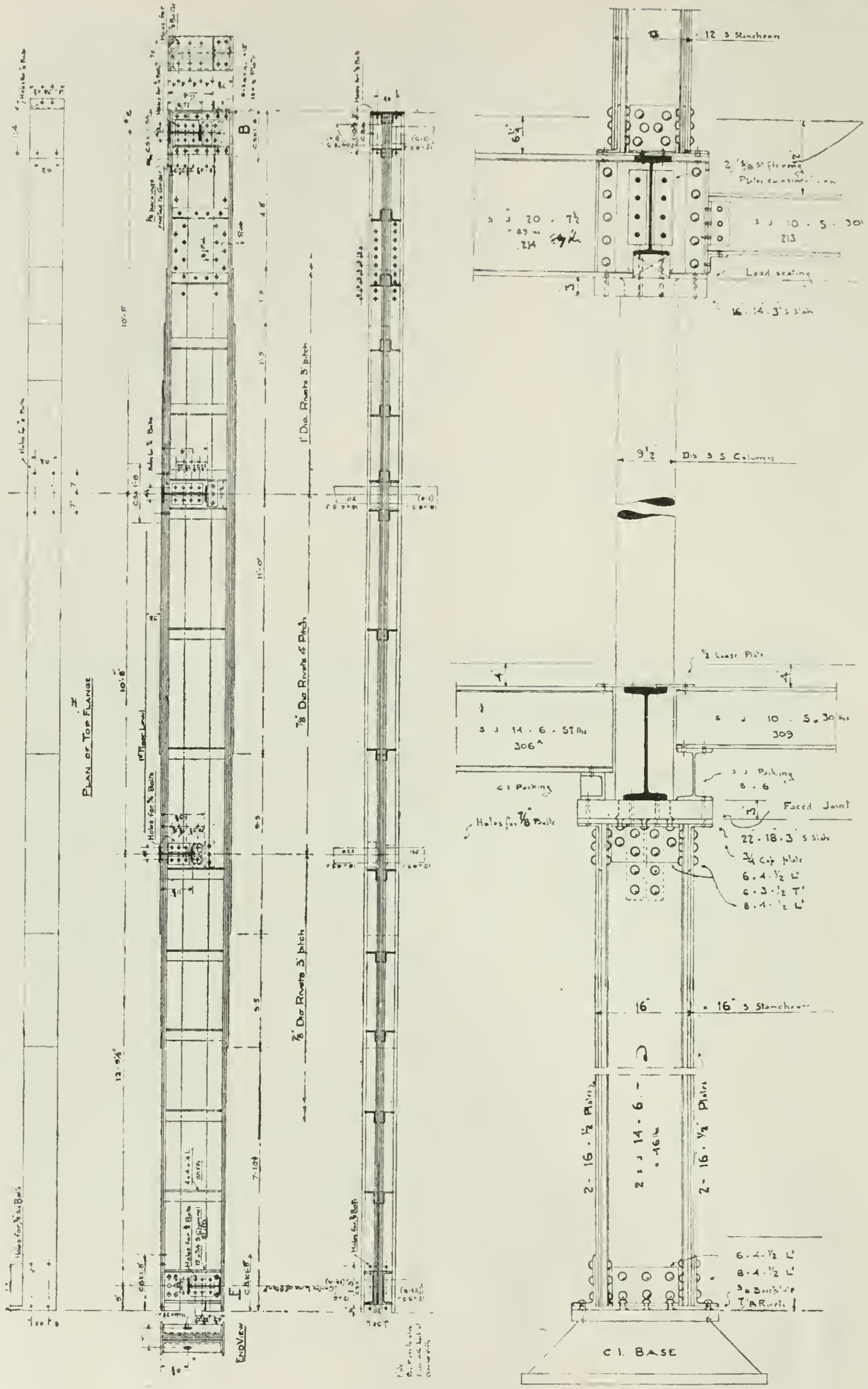


Fig. 8. Steel Details.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

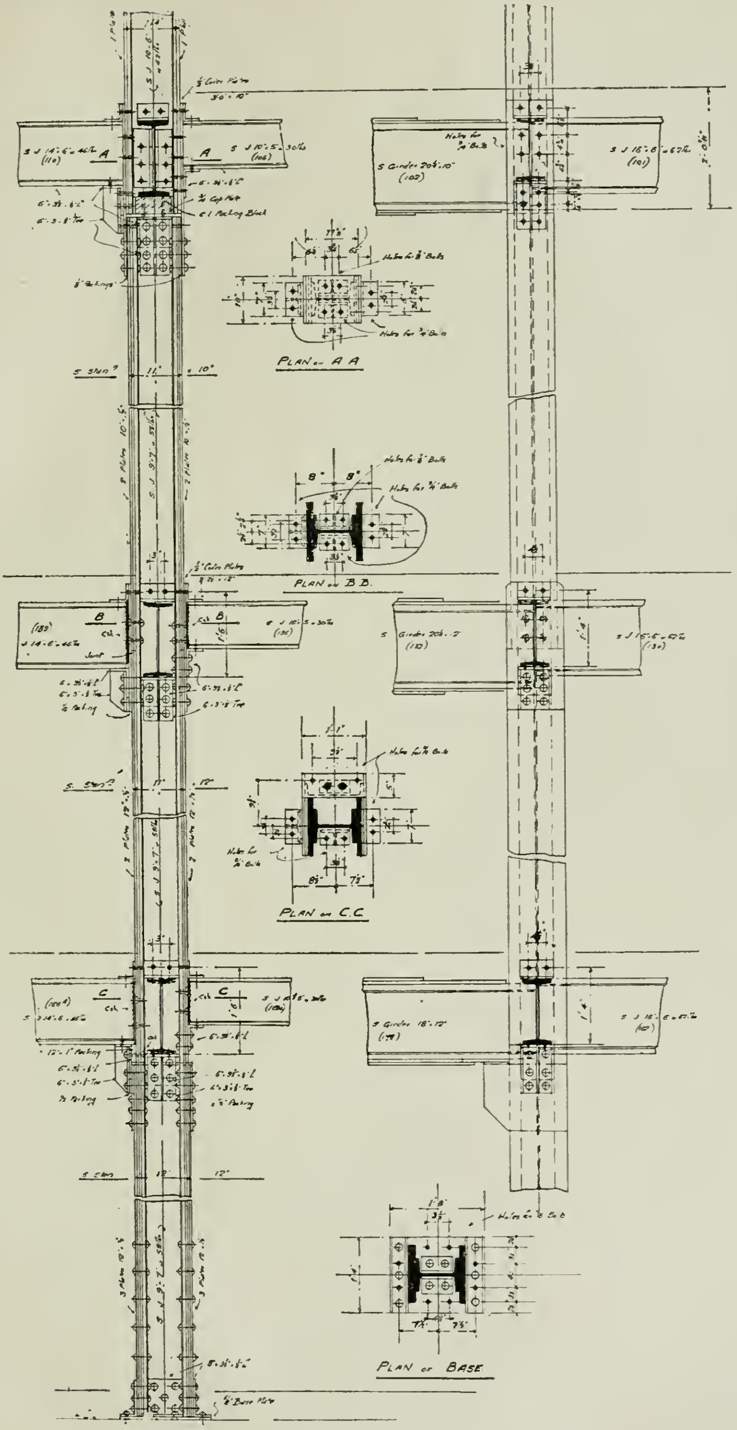


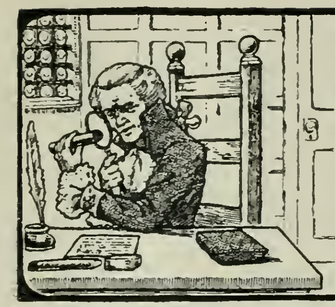
Fig. 9. Stancheon Details.
THE BRITISH COLUMBIA BUILDING, REGENT STREET, S.W.

supporting it is only 1 ft. 10½ in. thick and the cornice projects 4 ft. 3 in. beyond the face of the wall, special steelwork was necessary to hold it down. The detail of this is shown in *Fig.* 7. The 5 in. by 3 in. R.S.J. roof rafters are connected to a 6 in. by 5 in. R.S.J. running around the building, and the cornice is rebated to receive same, so that the weight of the roof prevents any tendency of the cornice to overturn. As a further precaution, a 5 in. by 3 in. R.S.J. runs in a groove between each stone of the cornice and helps to support the overhanging weight. These joists are cantilevered over a 6 in. by 4½ in. R.S.J. fixed in centre of the 1 ft. 10½ in. wall below, and with other end fixed to an 18 in. by 6 in. main roof supporting beam 4 ft. back from the frontage line.

An interesting feature of the structure is the use of Floretyle construction for the floors throughout. This consists of steel tyles placed in rows with a 4 in. space between them, and with reinforced concrete joists 4 in. wide and from 6 in. to 12 in. deep to carry the loads to the main supports.

The advantages claimed are that the light floortyles, which act as fillers, save a large amount of concrete and thus reduce the dead weight of the floor; the centreing is also simplified, as, in place of the usual close boarding, only a 7 in. plank is required under each reinforced concrete joist. *Fig.* 6 shows a section through the floor, which has been designed by the Trussed Concrete Steel Co., of Caxton House, Westminster. The floors are finished with 1¼ in. grooved and tongued boarding, either of fir or cedar from British Columbia. This boarding is nailed to fillets resting on the concrete, and to obviate the possibility of dry rot occurring these fillets are kept clear of wall and are grooved across to allow air to circulate under the floor. At intervals in the skirting metal gratings are inserted, and thus thorough ventilation is assured whatever the floors may be covered with.

The architect for the building is Mr. Alfred Burr, F.R.I.B.A., of 85, Gower Street, W.C., the contractors Messrs. Holland, Hannen and Cubitt, and the steelwork was carried out by the Aston Construction Co., of Eagle Wharf, Hoxton, N.



RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.
Chief Engineer to Trollope and Colls, London; Lecturer to 4th Year Students at City and Guilds Engineering College.

The following is the first of an important series of articles to be published in our journal.—ED.

INTRODUCTION.

Reinforced concrete is a material which has come to the front very much of late years, and is now acknowledged to be the most suitable material for constructing many works which would hitherto have been constructed in other materials.

One of the causes which has handicapped its development in England has been the fact that the design has largely been in the hands of persons who have little real scientific knowledge, and who are content to use formulæ and assumptions without satisfying themselves as to their accuracy and reliability.

It was with a view to partly removing this handicap that "Reinforced Concrete Design" was written a few years ago by Mr. P. G. Bowie and the writer, and it has been gratifying to find that the L.C.C. regulations have taken from this work the economical formulæ for bending moments in continuous beams, allowing for variable loading of adjacent panels.

The present work includes the verification of the resistance of singly reinforced concrete beams and the determination of the relative value of two proposed methods of calculating beams having compression reinforcement.

It also includes a new treatise of shear in concrete beams, and new rules and formulæ, which have a scientific basis and are of such a form as may conveniently be used by engineers.

Three separate series of test beams are then recorded, and it is shown by a comparison of the results of the new formulæ suggested, and the ascertained ultimate loads, that besides having a scientific basis the new formulæ have a far closer experimental justification than have the R.I.B.A. or new L.C.C. rules.

The experimental work was conducted in the years 1910 to 1914 inclusive, and the writer is indebted to the professors at the Northern Polytechnic and at the City and Guilds Engineering College for the facilities for experimenting they so kindly gave him in connection with his courses of instruction.

LIST OF SYMBOLS.

In accordance with the standard notation adopted in "Reinforced Concrete Design," R.I.B.A. (1911) Report and L.C.C. (1909) General Powers Act:—

a	Arm of the couple formed by the compressive and tensile forces in a beam.
a_1	Ratio a/d.
b	Breadth of a rectangular beam.
c	Compressive stress intensity on concrete.
c_s	Compressive stress intensity on steel.
d	Effective depth of a beam from top of beam to axis of tensile reinforcements.
h	Height or total depth over-all of a beam.
l	Length.
l_1	Equivalent point load span (see *Fig.* 37a).
m	Modular ratio, i.e., the ratio between the elastic moduli of steel and concrete $=E_s/E_c$.
n	In beams: distance of the neutral axis from the compressed edge of a beam.
n_1	The ratio n/d, *i.e.*, the distance between the neutral axis and the compressed edge divided by the effective depth of a beam.
p	Percentage of steel, i.e., $p=100r$.
r	Ratio of area of steel to area of concrete in single reinforced beams (compare p).
t	Tensile stress intensity.
t_1	Ratio of stresses $=t/c$.

AREAS, VOLUMES, MOMENTS, TOTAL LOADS, TOTAL FORCES AND CONSTANTS.

A	Total cross-sectional area of a pillar.
Ac	Area of compressive reinforcement in beams.
A_t	Area of tensile reinforcement in beams.
Ec	Elastic modulus of concrete in compression.
Es	Elastic modulus of steel.
M	Bending moment.
R	Resistance moment of the internal stresses in a beam at a given cross-section.
S	Total shearing force across a section.
T	Total tensile force.
W	Weight or load.

ANGLES, CONSTANTS AND MISCELLANEOUS.

θ	An angle.
μ	Co-efficient of friction.

DISCUSSION OF THE VALUE OF TESTS TO DESTRUCTION.

The method of experiment adopted in these researches is almost entirely that of constructing a series of test specimens, in which all the factors determining their strength are, as far as possible, kept constant, except the one factor immediately under consideration, and the specimens are then tested to destruction.

The "safe load" of the specimens is then calculated by the formulæ which it is sought to test, and by comparing this with the experimental "ultimate load" the factor of safety is determined. If this factor is found to be sensibly constant through a wide range of variation of the variable, and of the correct order, the formula is taken to be sensibly correct.

It is only fair to state that a school of thought exists among engineers which would base all calculations on the elastic limit, and not on the ultimate strength.

Members of this school point out that nearly all rational formulæ (as opposed to empirical)—and all those considered in these researches are claimed as "rational"—assume that plane sections remain plane after bending, and assume the proportionality between stress and strain. They argue

(1) that as these assumptions cease to be correct at the elastic limit the formulæ must not be used beyond it, and

(2) that the examination of ultimate strengths gives no indication of the conditions prevailing at ordinary loads. Further, they argue,

(3) that as the formulæ which are justified by consideration of ultimate strength only cannot be considered by them as quite rational, but are to some extent empirical, they are only safe for structures exactly similar in dimensions, form and other conditions to one already tested.

The only method which they allow is the study within elastic limits and formulæ based on such study.

The writer appreciates the logic of these arguments and does not neglect them through laziness or ignorance.

He feels, however, that though the study within elastic limits is free from the above objections, it has objections of its own, some of which may be enumerated as follows:—

(1) Some materials, particularly brittle materials, such as concrete, have no well-defined elastic limits, and to work on "a factor of safety of two on the elastic limit," which the school referred to prefers to a factor of four on the ultimate load, has very little meaning. This is particularly true in the case of reinforced concrete, where the concrete fails in tension when the steel is still well within its elastic limit, and in beams of such a composite material proportionality of load and deflection does not exist even within working loads, and a factor of safety based on its limit can, therefore, at best have only a very limited meaning.

(2) Experimental difficulties of measuring stresses within elastic limits are always considerable; but in the case of reinforced concrete are, in many cases, almost insuperable. With a long section of beam under constant moment it may be possible to measure the extension carefully, but even then the extension of the outside of the concrete near a steel rod is not necessarily that of the rod, which may have slipped to an unknown extent. If the steel is exposed for direct measurement of extension, the "adhesion" and other essential factors may be seriously altered. When we come to such matters as shear stresses and adhesion stresses in complicated arrangements of reinforcement the method seems to fail completely.

(3) For the above reasons the errors of experiment may lead to worse errors than the want of absolute rationality in the formulæ.

(4) Apart from the fact that the formulæ become less rational when the elastic limit is passed, it is really the factor of safety on ultimate loads which is of most immediate practical value. An engineer is more concerned with what load his beam will carry than at what load the proportionality of load and deflection ceases. Indeed, even if there were no experimental difficulties in the elastic limit method, it is doubtful whether it is always what is wanted. Suppose, for example, beam "A" will carry two tons without exceeding the elastic limit of any of its constituent parts and will not fail before eight tons, and beam "B" will carry two tons within elastic limits and will fail at three tons, most engineers would be willing to load "A" up to twice "B."

The writer, in his practice, endeavours to have regard to elastic limit *and* ultimate strength, and considers that an engineer who couples practical experience with theoretical and experimental knowledge and skill can generally determine which, in any particular case, is the determining factor.

Apart from what has been said, the writer considers that in the matter of exposing unexpected weak spots and of showing how they may be best avoided, the method of tests to destruction has important advantages, and for these reasons it was adopted in the following researches.

PART I.

MOMENT OF RESISTANCE OF SINGLY REINFORCED BEAMS.

(*a*) *Statement of Usual Theory and Formulæ Derived from it.*

The assumptions usually made are as follows:—

(1) The tension of the concrete is neglected, except in so far as it is required in adhesion and sometimes in shear.

(2) The modulus of elasticity of concrete is assumed constant and equal to 15.

(3) Plane sections remain plane after bending.

The usual formulæ are derived in "Reinforced Concrete Design," pages 26-37, and the following short precis is given only to enable the reader to make certain which are the formulæ which it is proposed to test.

Referring to page 234 for the list of symbols, and to *Fig.* 1, and remembering that the strain diagram is linear,

$$\frac{\dfrac{C}{E_c}}{\dfrac{t}{E_s}}=\frac{n}{d-n} \qquad (1)$$

Since the total compression will equal the total tension

$$\tfrac{1}{2}\,cbn=A_T\,t \qquad (2)$$

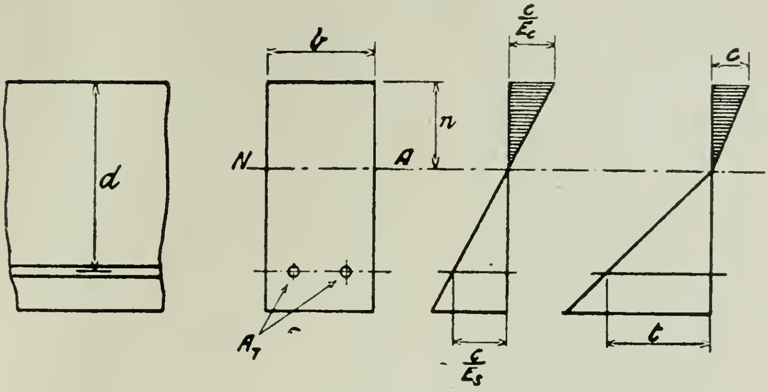
Substituting $r=$ ratio of steel $=\dfrac{A_T}{bd}$

$m=$ modular ratio $=\dfrac{E_s}{E_c}$

$$n_1=\frac{n}{d}$$

We obtain from equations (1) and (2)

$$n_1=\sqrt{m^2r^2+2mr}-mr \qquad (3)$$



Strain Diagram. Stress Diagram.

Fig. 1. Rectangular Beam under Single Bending.

The resisting moment of the beam is obtained by multiplying the total tension or the total compression by the radius arm.

$$R_c=\tfrac{1}{2}\,cbn\left(d-\frac{n}{3}\right) \qquad (4a)$$

$$R_t=A_T t\left(d_t-\frac{n}{3}\right) \qquad (4b)$$

c and t are the actual stresses in the beam under a particular condition of loading, and R_c and R_t are necessarily equal for simple bending.

If, however, we denote by c and t the *permissible* working stresses, the expressions may not be equal, and the correct value of R to be used is determined by the lower of the two.

(b) *Description of Experiments.*

Beams Nos. 1 to 8 were made as shown in *Fig.* 2. The beams are 10 ft. long, 12 in. deep, and 8 in. wide.

Beam No. 1 is plain concrete, and 2 to 8 have reinforcement gradually varying from ·234 to 2·37 per cent. placed in the shape of two bars, fish-tailed at their ends, at a distance of 1½ in. from the bottom. They were tested by a central point load on a 9 ft. span in a Riehle testing machine at the City and Guilds Engineering College.

The concrete is composed of

Ballast	4	parts	by volume
Sand	2	,,	,,
Cement	1	,,	,,

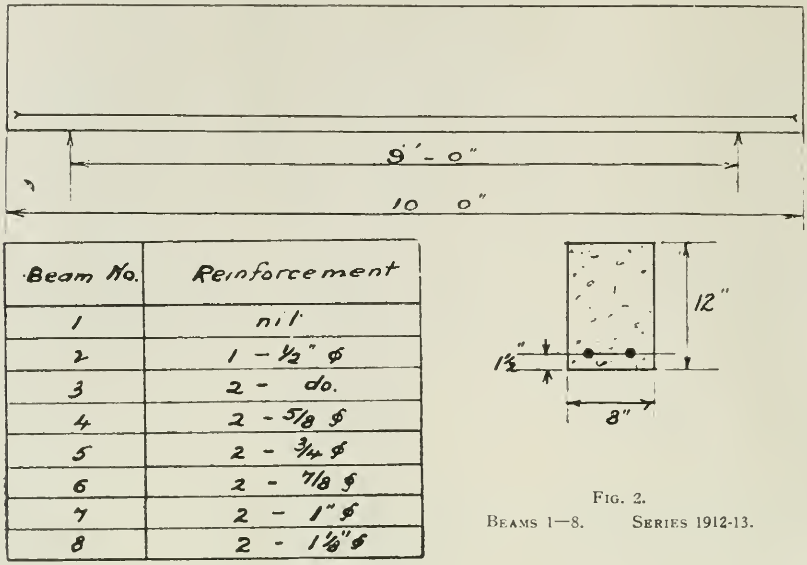
The ballast was crushed flint pebbles (from the Ham River Grit Co.) to pass ½-in. mesh and be retained on a ¼-in. mesh.

The sand was obtained from the same source, all through a ¼-in. mesh, and over 75 per cent. through ⅛-in. mesh.

The cement was Portland cement (from the Associated Portland Cement Manufacturers), breaking at about 700 lbs./in.² in 7 days tensile and about 900 in 28 days.

The steel was mild steel commercial bars to pass the B.S.S. for structural steel, with an elastic limit of about 17 tons/in.², and an ultimate strength of about 30 tons/in.².

All the materials were as used by the author in the construction of reinforced concrete workshops at Camberwell, and the beams were made by practical men working on this job.



Beam No.	Reinforcement
1	nil
2	1 - ½" φ
3	2 - do.
4	2 - 5/8 φ
5	2 - ¾ φ
6	2 - 7/8 φ
7	2 - 1" φ
8	2 - 1⅛" φ

Fig. 2.
Beams 1—8. Series 1912-13.

They were made in November 1912 and tested in February 1913 at the age of four months.

Beam No. 1 failed suddenly in tension at mid span with no warning.

Beams Nos. 2 to 4 failed by yielding in the tensile reinforcement at mid span.

Beams Nos. 5 to 8 showed the first cracks on the tension side, but failure occurred by crushing of the concrete in the top surface at mid span, as shown in *Figs.* 3 and 4. The large diagonal and horizontal cracks on these photographs, which might be taken to denote that failure occurred by diagonal tension or slipping respectively, were not formed until the beam had failed badly in compression and was no longer carrying its load (see also page 243).

Beams Nos. 5 to 8 failed more suddenly than beams 2 to 4, but not nearly so suddenly as beam No. 1.

(*c*) *Calculation of Safe Resistance by usual Formulæ.*

Beam 1 (plain concrete) was calculated by the formula

$$R = t. \frac{bd^2}{6}$$

Taking b as 8, d as 12, and t = 60 lbs./in.^{2} this becomes 11,520 in. lbs.

The central point load required to produce this 428 lbs.

Beam 2.

Effect. depth $= d = 10\frac{1}{2}$ in. (For symbols see page 234.)
Breadth $= b = 8$ in. (For diagram see *Fig.* 1, page 237.)
Area steel $= A = 2$ $\frac{1}{2}$-in. bars $= \cdot392$ in.^{2}.

$$\text{Ratio of Steel } r = \frac{\cdot392}{10\frac{1}{2}'' \times 8''} = \cdot00467$$

$$\text{Percentage } p = 100\ r = \cdot467$$

$$\text{Modular ratio } m = \frac{E \text{ steel}}{E \text{ concrete}} = 15$$

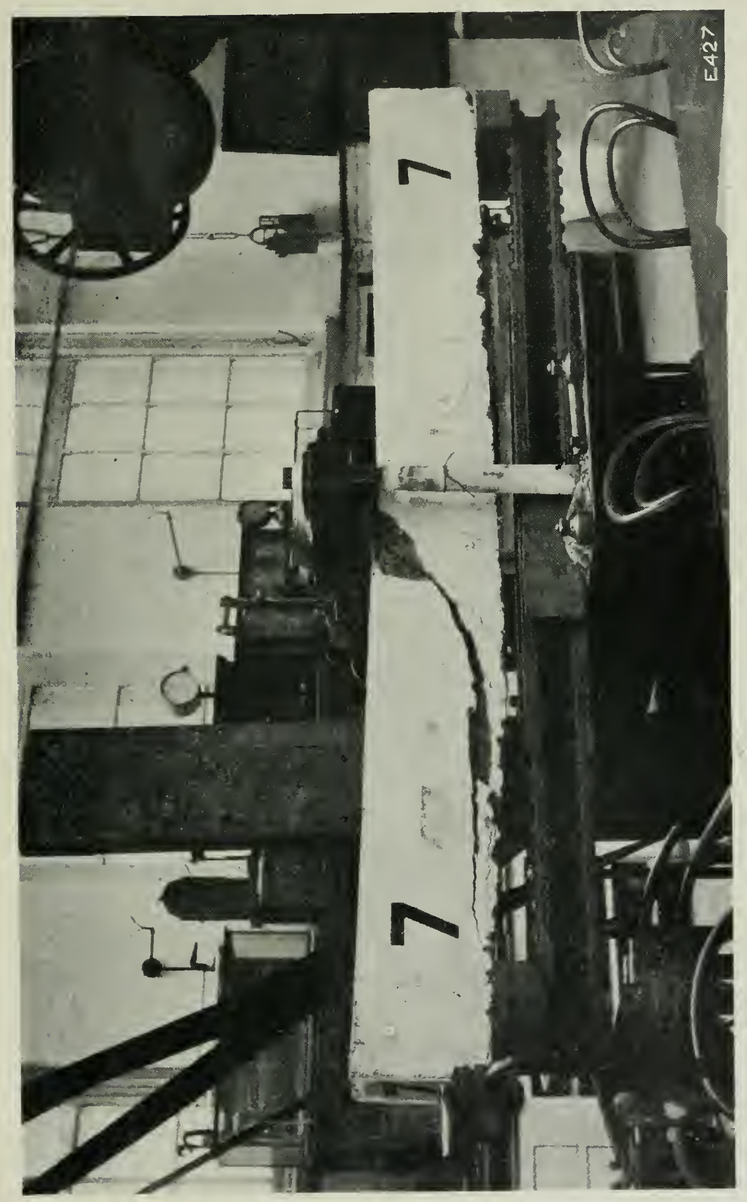


Fig. 3.

$$\text{Depth of neutral axis } n=[\sqrt{m^2r^2+2\,mr}-mr]\,d.$$
$$=3{\cdot}28 \text{ ins.}$$

$$\text{Radius arm } a=d-\frac{n}{3}=10\tfrac{1}{2}-1{\cdot}09$$
$$=9{\cdot}41 \text{ ins.}$$

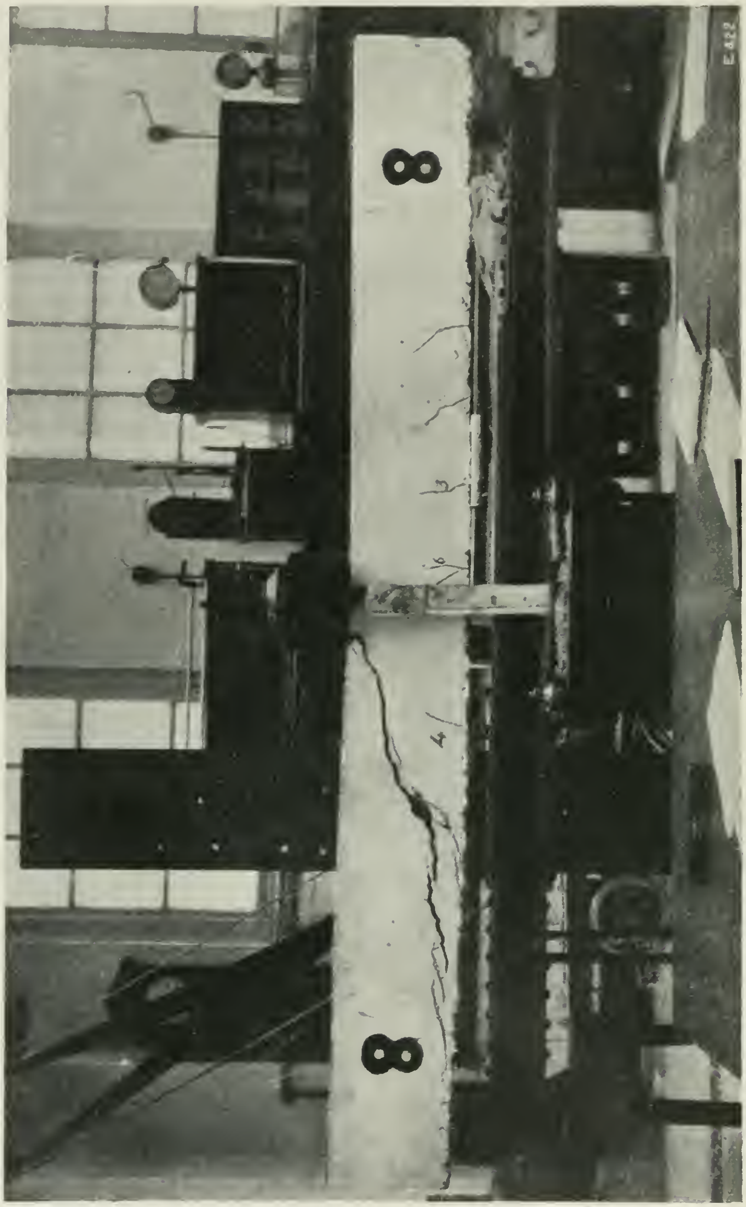


Fig. 4.

Safe tension resistance moment,

$$R_t = A.t.a.$$
$$= {\cdot}392 \times 16{,}000 \times 9{\cdot}41.$$
$$= 59{\cdot}000 \text{ in lbs.}$$

Central load on span of 108 in. to produce this moment is

$$W = \frac{4\,R_t}{108} = 2.180\ lbs.$$

As the percentage is under ·675 per cent., the safe compressive resistance moment will exceed R_t, and will, therefore, not determine the safe load.

The actual concrete stress, c, at the safe load may be found thus :—

$$R_t = \frac{c}{2} bna$$

$$\text{Whence } c = \frac{2R_t}{n\,a} = \frac{108{,}000}{3{\cdot}28 \times 9{\cdot}41} = 350 \ lbs./in.^2$$

Beam 3. Calculated ~~as~~ above.

Beam 4. As for Beam 2, we calculate

$A = {\cdot}61$ in.^{2}
$p = {\cdot}73$ per cent.
$n = 3{\cdot}88$ in.
$a - 9{\cdot}21$ in.

Safe compressive resistance moment.

$$Rc = \frac{c}{2} \times bna$$

$$= \frac{600}{2} \times 8 \times 3{\cdot}88 \times 9{\cdot}21 = 86{,}000 \ in.\ lbs.$$

$$\text{Whence } W = 3{,}180 \ lbs.$$

As the percentage is over ·675 per cent., the safe tensile resistance moment will exceed R_c, and will, therefore, not determine the safe load.

The actual steel stress. t, at the safe load will be

$$t = \frac{Rc}{Aa} = \frac{86{,}000}{{\cdot}61 \times 9{\cdot}21} = 15{,}300 \ lbs./in.^2$$

Beams 5 to 8 are calculated similarly.

Deductions.—The results of the experiments, coupled with the calculated safe loads, and the factor of safety found by a comparison of the two, are given in the following table :—

TABLE I.

Calculated.						Observed.		
Beam No.	Reinforcement.	"A"	"p"	"n"	Safe Res. Moment.	Safe Load.	Ultimate Load.	Factor of Safety.
		in.		in.	in. lb.	lb.	lb.	
1	—	—	—	6·0	11,520	428	1,650*	3·8
2	1–½ in. dia.	0·196	0·234	2·42	30,300	1,120	5,330	4·7
3	2–½ in. dia.	0·392	0·467	3·28	59,000	2,180	7,950	3·6
4	2–⅝ in. dia.	0·61	0·73	3·88	85,600	3,180	13,350	4·2
5	2–¾ in. dia.	0·88	1·05	4·42	95,500	3,530	14,450	4·1
6	2–⅞ in. dia.	1·20	1·43	4·96	105,000	3,900	18,050	4·5
7	2–1 in. dia.	1·56	1·87	5·46	114,000	4,230	19,150	4·5
8	2–1⅛ in. dia.	2·0	2·37	5·87	120,000	4,450	21,950	4·9

* To the load recorded on the machine has been added half the weight of the beam between supports = 450 lb.

The stress at top fibre of concrete, and in the steel, at the safe load are given by calculation as follows :—

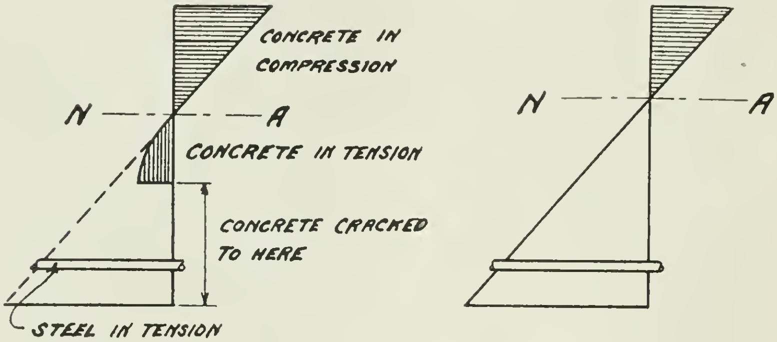
TABLE II.

Beam No.	*c.*	*t.*	Beam No.	*c.*	*t.*
1	60	—	5	600	12,200
2	350	16,000	6	600	10,000
3	478	16,000	7	600	8,400
4	600	15,300	8	600	7,030

It may be said, as a general deduction, that the factor of safety is substantially constant, having regard to the great variation in the percentage of steel (0 to 2·37) and to the unavoidable variations of hand mixed concrete.

The factor is also sufficiently near 4 to indicate that the formula is both safe and rational (the safe stresses in steel and concrete being based on a factor of 4 on the ultimate), particularly in the case of beams 3 to 5, where *both* materials are well stressed simultaneously.

In the case of beams with a small percentage, such as No. 2, the factor is rather greater than might be expected. This is no doubt due to the assistance of the concrete in tension, which is neglected in the theory underlying the formula, but is undoubtedly of some small value. It is realised by the writer that near the steel the concrete must be cracked before the steel can be usefully employed, but the concrete will continue to exert a small tensile stress near the neutral axis, as shown in *Fig.* 5.



Actual Stress Diagram at Rupture.

Diagram Assumed by Usual Formula.

FIG. 5. SHOWING THE ULTIMATE CONDITIONS OF UNDER-REINFORCED BEAMS.

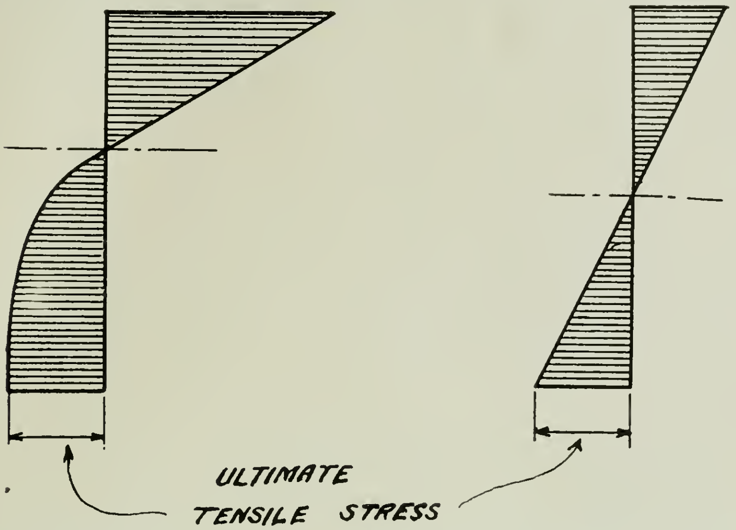
This stress is much more important than it would otherwise be owing to the rapid falling off in the modulus of the concrete as ultimate stresses are reached, which enables it to remain uncracked much further down, and to exert a much larger tension than would otherwise be possible.

This action is somewhat analogous to the well-known condition of a cast iron beam at rupture, which takes up a stress diagram, somewhat as in *Fig.* 6, and enables the beam to carry about twice the load than if a linear stress diagram were maintained.

Some action of this kind exists in all beams, but its value is only important, in proportion to the steel, in beams with a small percentage.

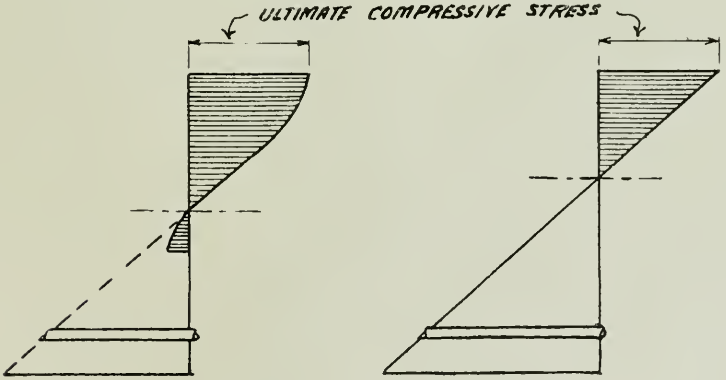
In the case of beams with heavy reinforcement the steel is not fully stressed at ultimate conditions, and in such cases the factor of safety also rises. (Note how the factor rises from beam 5 to 8.)

This is due to the falling off of the modulus of the concrete in compression, which enables the area of the compression flange—the limiting condition in such beams—to be greater than would otherwise be the case. This effect is shown in *Fig.* 7. Some designers have suggested making allowance for this by assuming the compression diagram parabolic instead of linear. The writer would strongly deprecate this, since the effect is only pronounced on very heavily reinforced beams, seldom used in practice, and a departure from the linear diagram would make many already sufficiently intricate calculations most unwieldy. The effect does not exist in beams lightly reinforced—which fail in tension, and the writer's opinion is that in practical work the effect is never so important that it need be dealt with except by recognising in it a small addition to the usual factor of safety.



Actual Stress Diagram at Rupture. Diagram Assumed by Usual Modulus Formula.

FIG. 6. SHOWING THE ULTIMATE CONDITIONS OF BRITTLE MATERIAL IN BENDING



Actual Stress Diagram at Rupture. Diagram Assumed by Usual Modulus Formula.

FIG. 7. SHOWING THE ULTIMATE CONDITIONS OF OVER-REINFORCED BEAMS.

The loads at which cracks were first noticed are given in Table III. :—

TABLE III.

Beam No	Cracking load.*	Safe load.
1	1,650 lb	428 lb.
2	4,700 ,,	1,120 ,,
3	4,650 ,,	2,180 ,,
4	2,800 ,,	3,170 ,,
5	4,550 ,,	3,530 ,,
6	5,750 ,,	3,900 ,,
7	4,950 ,,	4,230 ,,
8	not noted.	4,450 ,,

* The figures in this column have been increased by half weight of beam = 450 lbs.

Considerable irregularity is to be expected here as, no doubt, it depends largely on the keenness of the observer when the first crack is noticed, and the writer does not attach much accuracy or importance to the above figures.

They would seem to show, however, that, with plain beams and beams with under ·2 per cent. of steel, the first crack coincides with final rupture, but that for percentages of ·5 and upwards the first crack may appear just before or somewhat after the safe load has been reached. The significance of beam No. 4 is that if in a practical structure a crack be noted at working loads, it does not follow that the structure is unsafe, or that if tested to destruction it would have a factor of less than four.

It is worth noting that in beam No. 8, which sustained the greatest load, the maximum shear stress was :—

$$\frac{\frac{W}{2}}{a \times b} = \frac{10{,}975}{7{\cdot}54 \times 8} = 181 \ lbs./in.^2$$

This gives a factor of 3 on the usual working stress of 60, as against the factor of 4·92 developed in compression, showing that failure occurred by compression and not by shear,* although the presence of shearing stresses no doubt had some influence on the form of the rupture crack, as shown in *Fig.* 4.

It is also worth noting that in this beam the maximum adhesion stress was :—

$$\frac{21{,}950 \times 27}{8{\cdot}54 \times 2\pi \times 1\frac{1}{8}} \times 54 = 180 \ lbs./in.^2$$

This gives a factor of only 1·8 on the usual working stress of 100—and the 6-in. projection and fishtail have not been allowed for—showing again that failure did not occur by slipping. The cracks in *Fig.* 4, which indicate failure by shear, were only produced after rupture had taken place, when the beam was trying to support itself by arching, which concentrates the adhesion into a short piece near the support.† Hence they have no importance in this present study. We may, therefore, say as a final conclusion that engineers may use the formulæ in question with confidence that with good materials, workmanship, and supervision, they have a factor of four on the ultimate strength of their structure.

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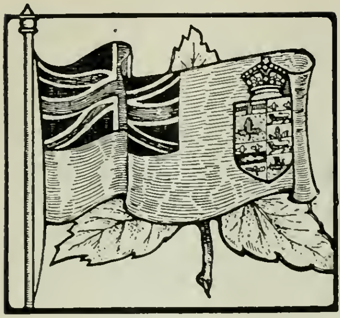
* Since the working stress in compression had been exceeded much more than that in shear.

† See Part III., *Fig.* 34.



A COMPLICATED CONCRETE CONSTRUCTION IN CANADA

ST. MICHAEL'S CHURCH, MONTREAL.

The following particulars and most of the illustrations of this very interesting building have been taken from our contemporary "Construction," of Toronto, and we are also indebted to the architect, Mr. Beaugrand-Champagne, for the elevation shown in Fig. 4.—ED.

A STRIKING example of the adaptability of concrete to complicated structures is given by the St. Michael's Church now being completed, corner of St. Urbain and St. Viateur Streets, in Montreal. The church proper covers an area of about 170 by 90 (exterior dimensions). There are really no columns in this church, and the whole structure is built of plain and reinforced concrete. The style is Byzantine, and the illustrations reproduced here give a better idea of the design and appearance of the building than any lengthy descriptions.

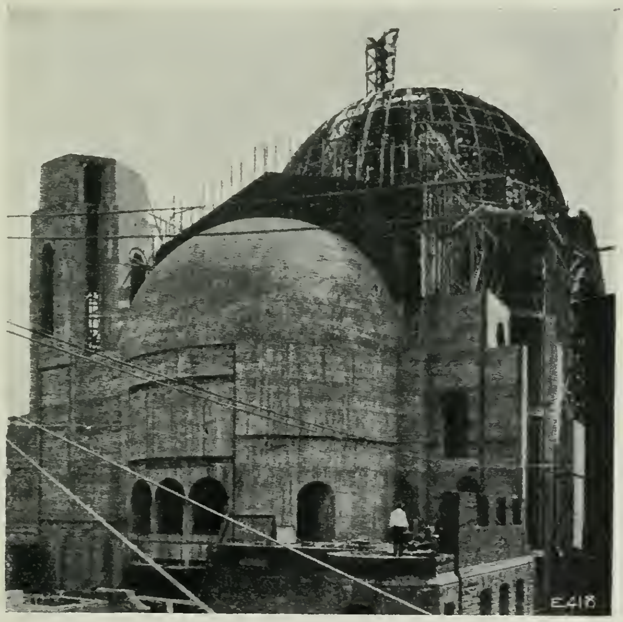


Fig. 1. Concrete Dome, showing Forms in place.
ST. MICHAEL'S CHURCH, MONTREAL.

The lay-out, not only from an architectural but also from an engineering point of view, was made in all its detail by the architect. It remained for the engineer only to check up the stresses in the concrete and provide the necessary steel to take the tension stresses, and in doing so it was easily ascertained that details of construction were also gone into by the architect, as no changes had to be made, and the church is built in strict accordance with the original plans of Mr. Beaugrand-Champagne, architect, of Montreal.

The church is founded on rock. The basement ceiling is carried by flat arches, 54 ft. clear span, having a raise of 30 in. only. The arches are 18 ft. centre to centre, and are connected with a flat slab 7 in. thick

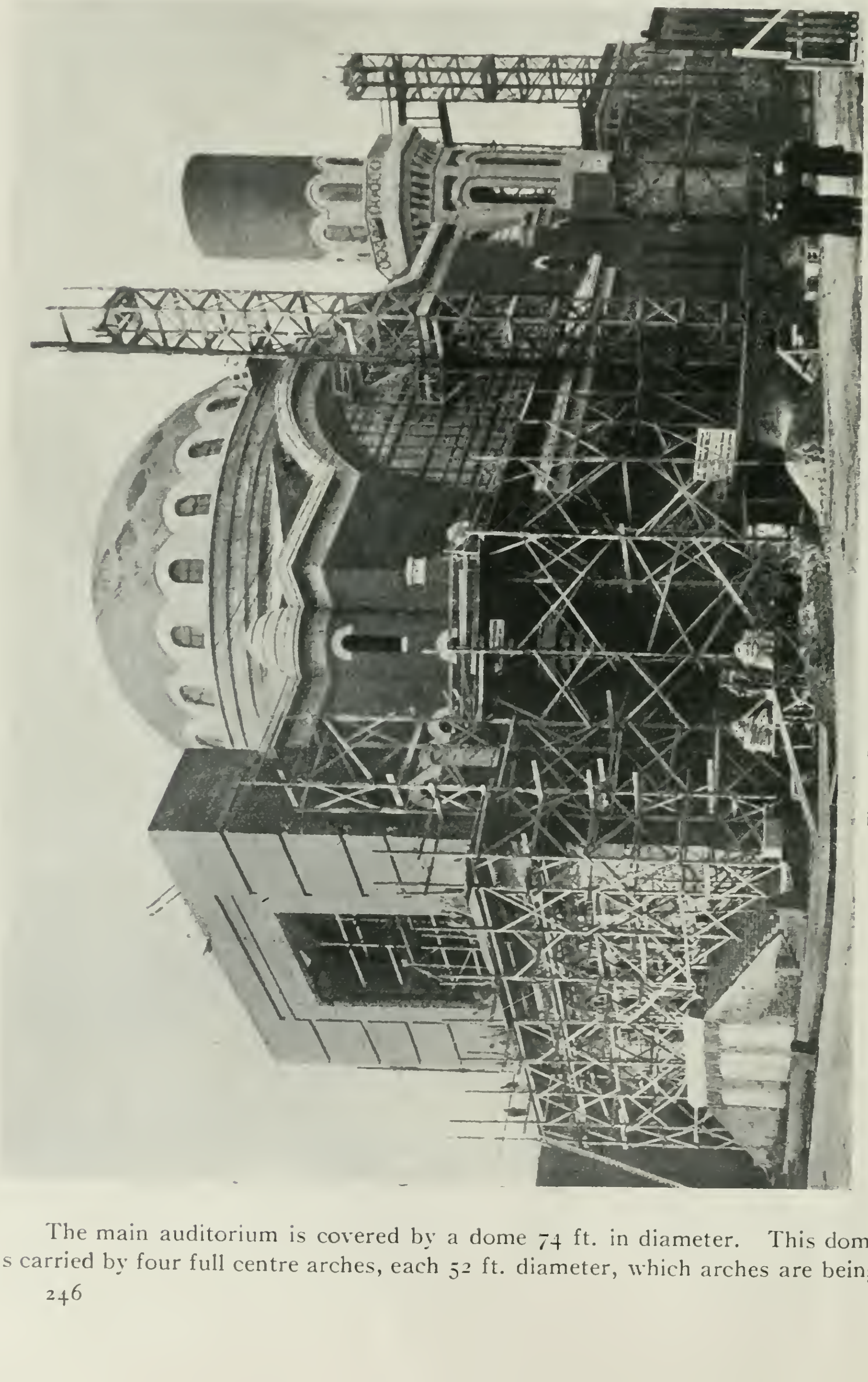


Fig. 2. General View of Building in course of construction.
St. Michael's Church, Montreal.

The main auditorium is covered by a dome 74 ft. in diameter. This dome is carried by four full centre arches, each 52 ft. diameter, which arches are being carried down to rock by four strong tower abutments. Arches, cantilevers, the dome proper, etc., are clearly shown on the illustrations. The dome is

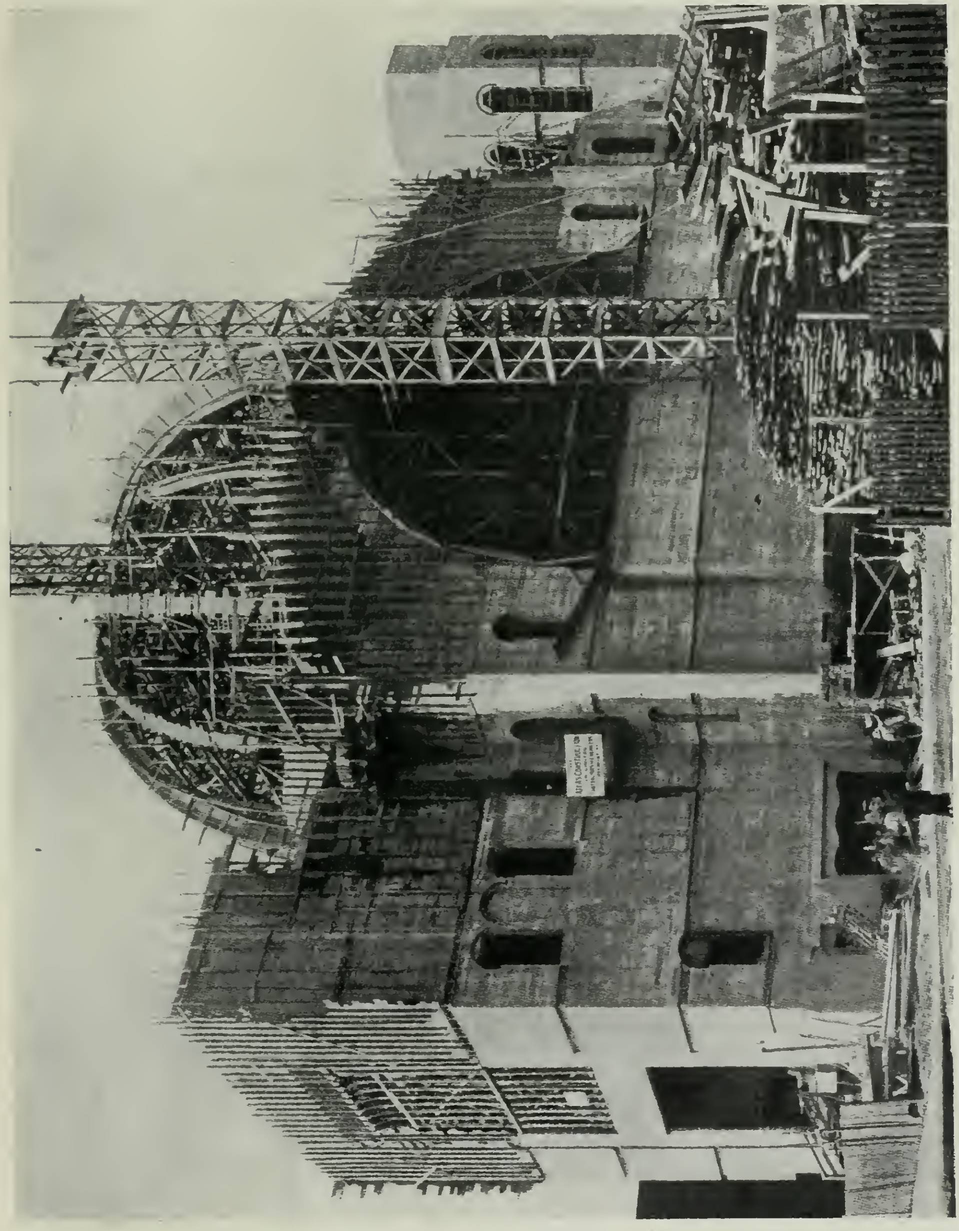


Fig. 3. Front and Side Elevations, also showing formwork of Dome.
St Michael's Church, Montreal.

about 118 ft. above the sidewalk and 110 ft. above the auditorium floor, and the tower is 170 ft. high.

The outside walls are all covered with Greendale brick and terra cotta, as

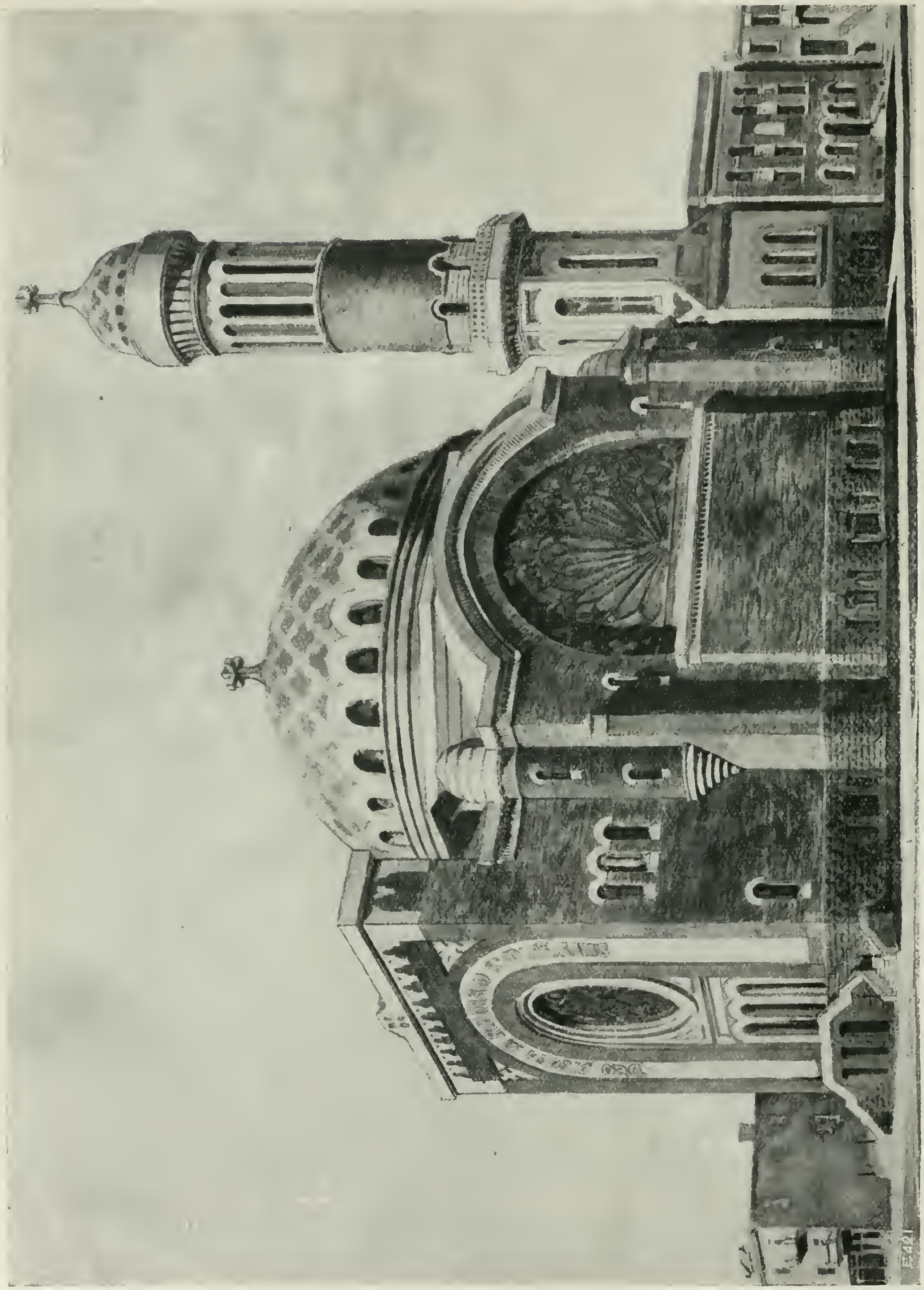


Fig. 4. Elevation.
St. Michael's Church, Montreal.

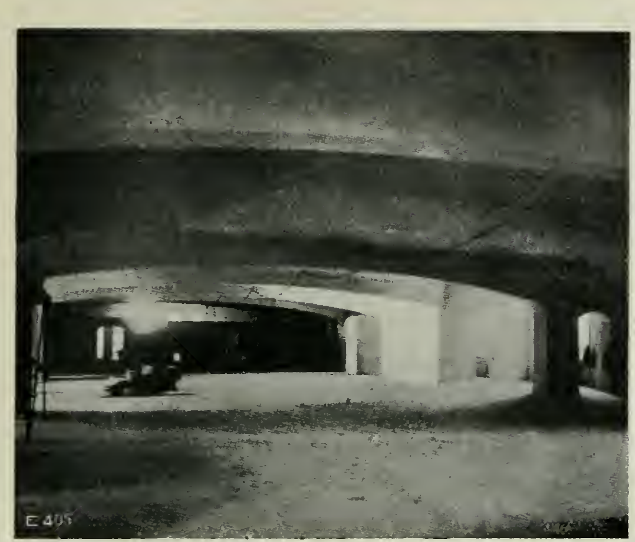


Fig. 5. Reinforced Concrete Beams in Basement.
St. Michael's Church, Montreal.

the illustrations show. The dome and roofs, however, are finished in concrete, the dome having received a coloured waterproof cement finish about 1 in. thick, showing green shamrocks on a white field. The green colour was obtained by mixing a green pigment with the ordinary cement, and the white is obtained by the use of white cement.

The contractors for the building were the Atlas Construction Co.

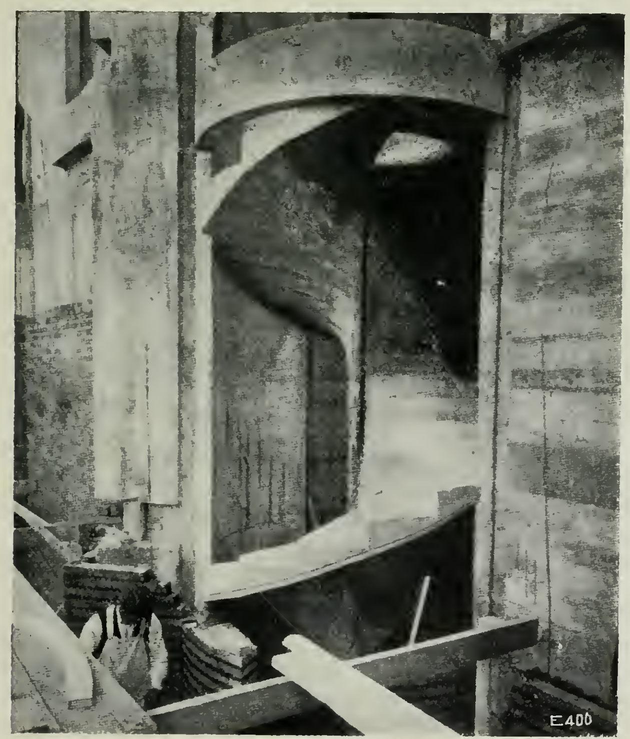


Fig. 6. Detail of Concrete Stairway.
St. Michael's Church, Montreal.

THE PRINCIPLES OF MECHANICS.

As a recent book on Applied Mechanics[*] *has attracted much attention amongst Teachers and Engineers, we have decided to submit to our readers a critique of those parts of the book which deal more particularly with the fundamental principles of statics and dynamics applicable to "Concrete and Constructional Engineering."—ED.*

WEIGHT, MASS, INERTIA.

In the average book on mechanics, plain engineering principles are obscured by verbiose disquisitions showing that the mystical "division of the weight (W) by the gravitational acceleration (g) is the inertia of the body," and "the inertia of the body is its mass" (M or m), and "the mass is the quantity of matter in the body"; but "the quantity of matter in the body" is a different thing to its resistance to motion," which is its inertia, and showing generally that "That is, which is not," etc.

Truly the average school book on this subject reads like a jumbled mistranslation of the "Mechanics of Archimedes" converted into an Athanasian Creed for Engineers.

Imagine our surprise, then, in discovering a book which sets out the main principles of mechanics stripped of the weary verbiage about poundals and the mysterious trinity of weight, mass, and inertia.

The author has evidently arrived at his conclusions "by brooding over his subject in solitude," but he has arrived at definite conclusions analogous to those of Sir George Greenhill, who states that:

"It is important that g should not stray from its place in equations and take cover under W, or else the old mystification comes in again, where $\frac{W}{g}$ has been replaced by a single letter, M or m—a mere lazy algebraical device at first, to save trouble in writing and printing, but exalted forty years ago into a profound dynamical principle, to the confusion of every novice in dynamics."

Sir George Greenhill also notes with approval "a return in the Royal Military Academy to the gravitation unit of force in dynamics as more tangible for application to practical engineering than the absolute system (the poundal), introduced into theoretical instruction about forty years ago." Mr. Andrews's book is therefore suitable for the engineers of the Royal Military Academy. It is also suitable as a work of reference for those practical engineers who have had to learn mechanics from books loaded up with impractical units and mystical definitions of doubtful validity.

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[*] Introduction to "Applied Mechanics," by Ewart S. Andrews, B.Sc., M.C.I. Published by Cambridge University Press. Price: 4/6.

In order that the book may be still further improved in future editions, a few friendly suggestions will be put forward for the author's consideration.

EQUATIONS *versus* DIAGRAMS.

The general treatment is based more upon graphical conceptions than upon purely mathematical analysis, because the author is of opinion that the mind of the engineering student reasons more clearly from diagrams than from symbols; but the author is hardly fair to the analytical method, because some of his symbols are utterly irrelevant, and are very detrimental to the clarity of his formulæ. For example, it is well that W should be the abbreviation for *Weight* and a for *acceleration;* but why should S, instead of R, represent *Resistance* (page 45)? Was "*Stopistance*" intended?

There is no risk of confusion with the term "Reaction," which occurs in beam formulæ.

The adoption of mnemonic notation would certainly "enable the mind of the engineering student to reason more clearly from symbols" than it does at present.

There are many thousands of engineers who cannot forget real terms, and who cannot remember the meaning of misleading symbols. The author has stepped into the foremost rank of technical writers, so that he is one who matters, and whilst he agrees in principle that the notation should follow the nomenclature, he frequently overlooks the obverse axiom that the nomenclature should follow the notation, like the twin revolving weights of an engine governor. In his writings we have frequently noticed the divorce of notation from nomenclature. For example, he says:

"E = Young's modulus," whereas if he intends using the symbol E he could have easily fixed it in the memory of his readers by saying, "E = Young's *elastic* modulus."

Again he says, "F = Tractive effort," whereas he might have said, "F = Tractive *force* or effort." By omitting the word of which the symbol is the significant residue he unintentionally and unconsciously opens wide that very door by which chaos has entered for the last three thousand years. The adoption of the mnemonic principle would bar that door for ever. Symbols should be the significant residue of the written words, and not the initial letter of some abandoned word.

In spite, however, of the author's frequent or occasional disregard of the association between nomenclature and notation, the book is probably the best introduction to mechanics which has appeared for a generation, and we only make these suggestions with the hope that future editions of the book might approximate more closely to the ideal and lucid introduction for which all engineers have been waiting until now.

A very little change here and there will be sufficient. The book does not appear to be free from occasional errors of definition, and it would be a pity if readers were thereby misled into losing marks at examinations, or fell into a confused state of mind.

SAFETY FACTORS.

In pursuance of the wish to improve the book's utility, the attention of author and readers is invited to the following further points.

On page 151 there is some (probably accidental) confusion between the "safety factor" and the "working factor." The ratio,

$$\frac{\text{(Breaking Stress)}}{\text{(Nominal Working Stress)}}$$

or the ratio

$$\frac{\text{(Elastic Limit)}}{\text{(Estimated Maximum Stress)}}$$

should be both referred to as safety factors; but the reciprocals of these ratios should be known as "working factors."

For example, the ratio $\frac{\text{(Estimated Maximum Stress)}}{\text{(Elastic Limit)}}$ and the ratio $\frac{\text{(Nominal Working Stress)}}{\text{(Breaking Stress)}}$ are both "working factors." Expressed symbolically

$$\text{Working factor} = \frac{1}{\text{Safety factor}}$$

We notice that the author states that "The term 'factor of safety' is used very loosely," and we agree with him. It is.

STRAINS AS RATIOS.

We also notice that the author introduces the term "unital strain," and then, when he gets on to the practical application of the term, he drops it and uses the word "strain" in a sense which conflicts with his own definition of "strain."

For example, he states:

$$\frac{\text{Stress}}{\text{Strain}} = E\text{; also}$$

$$\frac{\text{Transverse strain}}{\text{Longitudinal strain}} = \text{Poisson's Ratio}$$

These are both correct expressions, but they conflict with his own definition of strain. Perhaps the simplest way to consistency and clarity might be to drop the term "unital strain" and substitute the following or some similar definition.

Strain may be defined as the change in dimensions or form *per unit of length or per unit of volume* of material when that material is acted upon by external forces.

The author's definition of strain does not fully satisfy Hooke's law as quoted by the author—viz.: "Strain is proportional to stress."

His definition of strain really amounts to a synonym for total deformation.

BULK MODULUS.

His definition of bulk modulus or volume modulus (page 145) appears to be inverted. Surely the bulk modulus is the hydrostatic (or other similar) force per unit of area divided by the change in volume per unit of volume.

Or in the general case:

$$\frac{\text{Stress of any kind}}{\text{Corresponding strain}} = \text{Corresponding Elastic Modulus}$$

NEUTRAL AXIS, NEUTRAL PLANE.

On page 188 there is a figure (No. 105) which will cause confusion in the minds of students and may lead to loss of marks at an examination. There is a side elevation of a beam, and the "trace of the neutral plane" is referred to as the neutral axis. In the side elevation the neutral axis would be shown as a point.

It is only in the cross-section that the neutral axis is shown as a line. Of course the author knows this, but his diagram should be altered to read, "neutral plane," not neutral axis. It is manifestly an accidental oversight.

We are confirmed in this opinion by the summary of Chapter xii., page 201, where the author correctly states that the "neutral axis of the beam is *the line in the cross-section* which receives no stress or strain."

SHEAR STRAIN.

On page 141 the author, in dealing with shear strains, states that the angle β approximately equals x/l. He passes this by without comment, and apparently overlooks the fact that whilst he, as a mathematician, will instantaneously recognise that the angle β is obviously measured in radians, yet the majority of his engineering readers will be prone to say that $x/l = \tan \beta$ where β is the angle *in degrees*. A footnote might be added to clear this point, or he might say $x/l = \beta$ where β is the angle in *radians*.

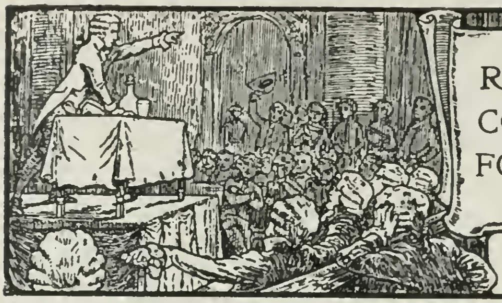
PILE DRIVING.

His paragraphs on pile driving are very good and show quite clearly that pile formulæ for wooden piles (with light rams and long falls) are not necessarily suitable for reinforced concrete piles (with heavy rams and short falls). It is proposed to discuss this very important part of the book in a later issue of this journal.

CONCLUSION.

The author has earned our thanks for many good things in this book. Amongst many other points we owe him hearty thanks for delivering us from the curse of the "poundal" and the worship of "inertia" and "mass."

May every member of every academic and scholastic examining body read this book through, and abandon the "toy units" and the intangible abstractions which engineers abandon the moment they turn to the practical problems of their working life.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE INSTITUTION OF CIVIL ENGINEERS.

THE MAIN DRAINAGE OF CAIRO.

By CHARLES CARKEET JAMES, M.Inst.C.E.

The following is an abstract of a paper read recently at the above Institution.

The paper commences with the history of the steps taken by the Egyptian Government for the drainage of Cairo from 1885 to 1906, and then describes the scheme as subsequently designed and carried out by the author, and officially inaugurated by H.E. the Minister of Public Works on March 22nd, 1915.

The City of Cairo and suburbs included in the scheme covers an area of 7,538 acres. It is drained on the sectional and gravitation systems, the sectional portion using compressed-air ejectors. After giving details of the rainfall, water-consumption, population, and sanitary conditions of the city, the paper deals with the treatment of surface water for the whole city and suburbs, and describes the machinery, ejectors and mains installed for dealing with about 9 million gallons per day.

Next the sewer reticulation and the compressed-air system and its machinery are dealt with. Sixty-three ejectors in cast-iron tubbings have been sunk, with 50 miles of cast-iron air-mains and sealed sewage-mains. The air-compressing plant consists of four steam-driven compressors, each capable of compressing 1,770 cubic feet of free air per minute to a pressure of 22 to 25 lbs. per sq. in.

The main collector is 14,900 yards in length, 5 ft. 3 in. in internal diameter, constructed in cement concrete, and laid with a gradient of 1 in 2,500. The construction of this collector, the plant used, and the methods and cost of unwatering the trenches are described.

The next section deals with the screening-chamber, sump and main pumping-station at Kafr-el-Gamus and gives details of their design and working. At Kafr-el-Gamus the sewage is received from the main collector and pumped to the purification-works and farm at Gebel-el-Asfar. The construction of the sump is briefly touched upon. The pumps, boilers, etc., are designed to deliver 50 cubic metres (11,000 gallons) of sewage per minute against a head of 250 ft. The plant consists of four units, three of which are capable of dealing with the maximum flow. The pumps are of the triple plunger type, and are placed immediately over the sump. Each steam-engine develops 200 h.p. at a normal speed of 22 revolutions per minute, but is capable of developing 360 h.p. at the maximum speed of 32 revolutions per minute. The engines are arranged for quadruple expansion, and each has its own condenser placed under the engine floor.

The rising main is 36 in. in internal diameter, constructed of cast-iron, and $7\frac{1}{4}$ miles in length. The flow passing through this main is registered by a Venturi meter, and controlled at intervals by sluice and reflux valves. A complete description of this main and of the testing of the pipes is given.

The purification-works at Gebel-el-Asfar are designed to treat 11,000,000 gallons per day through six hydrolytic tanks and eight continuous filter-beds with storage tanks for holding up the night flow. A description of the method and results of treatment is given, and the necessary machinery for supplying the power needed for driving the pumps, distributors and other mechanical appliances and for the lighting is described. The plant consists of three semi-Diesel oil-engines of 60 h.p., each direct coupled to 45-kilowatt dynamos, from which the electrical energy is transmitted to various points by overhead cables.

For the Gebel-el-Asfar farm about 3,000 acres of desert land has been reserved. The methods of irrigation and cultivation, and the earlier experiments carried out to decide upon the agricultural policy to be followed, are described, as well as the accommodation provided for the staff and farm labourers; and the prospects of the farm with regard to cultivation and returns are discussed. Owing to the absence of rain, desert land only requires continuous irrigation, and in the vicinity of a city such as Cairo it should prove very remunerative

Finally, the system of taxation to meet the cost of the drainage and the costs of the scheme are dealt with.

THE AMERICAN CONCRETE INSTITUTE.

REINFORCED CONCRETE IN SEWERS.

By W. W. HORNER

Engineer in Charge, Division of Design—Sewers and Paving, Board of Public Service, St. Louis, Mo.

The following are Extracts from a Paper given before the American Concrete Institute at their last Convention in February of this year.—ED.

INTRODUCTION.

About the year 1900 reinforced concrete had been taken up in many fields of construction and applied to long-span arches, and the advantages of its use in sewer construction were soon appreciated. During the next five years many examples of concrete sewers are found, although, with a few exceptions, the reinforcement consisted of wire mesh or expanded metal, and there was an evident tendency on the part of the majority of engineers to use rather heavy sections, similar to the plain masonry types. A few examples are also found of extremely radical designs involving very light sections heavily reinforced. These two extremes suggest the difference between the sewer engineer adapting his designs to reinforced work and the concrete expert breaking into the sewer field. In the last ten years all of these ideas have been through the melting pot, and we are beginning to find certain standard types of reinforced concrete sewers used generally. These are the horseshoe type, varying in proportions from the semi-circular to those of about equal height and width, and the elliptical, usually constructed as a five-centered arch. Of exceptional advantage under certain conditions, the box or slab section is often employed, but under average conditions it is less economical than the other types. The circular sewer is difficult to construct in what is known as "monolithic" work, that is, if built in place, but the circular reinforced concrete pipe developed along other lines has become standard construction in size up to about 8 ft. It is unit work and may be considered as a factory product, and for that reason a much more satisfactory concrete can be secured through its use than is generally obtained in monolithic work.

The great advantage of the reinforced arch for use in sewer construction lies in the economy in material. In large sizes, 8 ft. or over, the reinforced concrete sewer requires only from 60 to 80 per cent. as much masonry as the "gravity" type. Also where the amount of concrete per foot is sufficient to warrant an efficient plant, the unit cost of the concrete should be somewhat less than that of good brick masonry. In addition to the saving in masonry, there is usually an accompanying difference in excavation, and in deep work this may be a material consideration. Finally, there may reasonably be a difference in required size of sewer due to the greater smoothness of good concrete work, which amounts to between 5 and 10 per cent. reduction in mean diameter.

CONSTRUCTION.

There can be no question that reinforced concrete is the natural engineering solution for the problem of large sewers. If reasonably designed and carefully constructed it gives the best and cheapest sewer. In the hands of a designer not thoroughly familiar with the conditions surrounding sewer construction and maintenance, or of a contractor not experienced in reinforced concrete work, it is likely to be a dangerous material, and it is a much too common occurrence that work is handled under just these conditions. The fact that many of these sewers are built by contractors whose whole experience has been with massive masonry, has not tended to add to the safety of the finished work.

When the excavation is complete, the invert is concreted. In rock or in dry ground, this can be done efficiently, but if water or mud is present, a portion of the concrete is sure to be unsatisfactory. With very bad bottoms, it is often necessary to place a raft of extra concrete and allow it to set before attempting to place reinforcement. If such conditions appear possible, good practice will provide for this work in both specifications and estimate, and may reasonably provide for under-drains to relieve the new concrete of damage from water flowing from the trench ahead. Unless the specifications are to provide that the work is to be expensively delayed, it should be noted that there will be quite an amount of working over and across the new invert while the concrete is setting, and exposed bars left for splicing are likely to be bent and jarred and their bond value in the invert concrete decreased. Also, because of these stub bars, it is usually impracticable to protect that portion of the invert from dirt and rubbish. While it is generally the custom to leave the sides of the invert rough to furnish a bond with the arch, it is an open question whether the finishing of this concrete smooth is not the lesser evil, as it can then be thoroughly and efficiently cleaned before additional concrete is laid.

Before the arch forms are set, it is necessary to remove cross bracing up to the crown level, and it must be replaced with verticals bedded in the new invert and cross-braced above the crown. Even with the most careful work, this will produce some disturbance with the sides of the trench, and may even allow a bulging of the side plank enough to protrude within the neat measurements of the sewer. To widen and rebrace the section from the surface down may be expensive and hazardous as well as disorganising, and the engineer often faces the problem of modifying the section instead. The writer recalls instances where the contractors have even asked permission to fill the whole trench to the top of the sewer with concrete at their own expense, rather than to attempt the re-excavation, and the construction engineer must be able to decide whether the deficiency in thickness at the sides can be compensated in this manner.

Collapsible steel forms are usually favoured for the arch, and if kept well cleaned and oiled produce the best interior surface, but well-made wooden centres carefully planned will result in more satisfactory work. The choice will usually depend on the contractor's organisation and schedule, as greater progress with one outfit can be secured if the collapsible forms are used.

Under the conditions prevalent in this work, the setting and holding of the arch reinforcement in accurate position is especially difficult, and the importance of accuracy is rarely appreciated by foreman and labourer. When properly set, the rods are difficult to hold during concreting, as it is often necessary for the men to stand on the reinforcing while spading the concrete. The cost of special chairs or holders for the reinforcement is usually well warranted.

The placing of the concrete is made especially difficult because of the double mat of reinforcing bars, which tend to break up the stream of concrete and to cause a separating out of the aggregate. The concrete is also likely to be lowered in quality by an almost unavoidable leakage of water. The concrete is also contaminated to some extent by earth and rubbish knocked from the surface into the forms. There occur, also, even in the best regulated work, certain small slips of earth from between the side planking, and it is possible that portions of the clay or loam may be churned into the concrete before it can be cleaned out from the tangle of reinforcement.

In view of the unavoidable construction contingencies inherent in this class of work, the writer would recommend to the designer the following prescription :—

1. Use the best grade of concrete and considerable excess of mortar.

2. Do not work concrete at more than 450 lb., unless the construction conditions are to be exceptionally favourable.

3. The concrete cover outside of the steel should be at least 2 in.

4. Use a minimum thickness of concrete of about 9 in., unless the work is close to the surface, or is to be built under very favourable conditions, and increase this minimum and also the cover over the steel if the conditions are likely to be very unfavourable.

5. Specify the setting of the reinforcement with especially designed holders. These might be made of cast iron and left in the concrete.

6. If there is any possibility that the trench will be very wet, provide for a sub-base of concrete and provide means of keeping the trench water away from the work, if possible.

7. To secure a concrete that will flow into place with the least assistance, a specification for a 2½- or a 3-minute mix should be seriously considered, as might also the use of hydrated lime. This would naturally result also in a denser and more waterproof concrete and might be a very considerable factor in prolonging the life of the reinforcement.

8. Provide for a lining of vitrified brick for the invert, or at least provide an excess internal area to allow for such a lining at some later date. This is of more importance in maintenance than in construction, as under average conditions it is easier to obtain a reasonably smooth invert with the brick than to attempt to finish the concrete itself.

9. Specify cold weather methods. Concrete can be placed satisfactorily and economically at even a zero temperature, if proper precautions are taken. It should be noted, however, that it is quite easy to over-heat the finished concrete and to drive out a portion of the water.

In the St. Louis work, it has been customary to heat the water by turning exhaust steam into the watertank whenever the temperature goes below 40 degrees or whenever there is frost in the materials. In colder weather, steam coils are used in the sand storage piles and often in the piles of coarse aggregate. It is also customary in freezing weather to place salamanders inside the arches and to hang tarpaulins at each end of the unit constructed. The top of the sewer has generally been protected by a covering of tarpaulin or plank, on top of which manure is piled.

LOADING.

The loads to be considered are first, direct weight of the earth filling; second, horizontal or inclined pressures induced by the weight of this filling and the adjoining earth; third, pressures due to transmitted surface loads.

The relative values of these pressures will depend on the depth and size of the sewer and on the use to which the ground surface may be put.

Vertical Loads.—It is always safe and usually reasonable to design for vertical loads equal to the full weight of the superimposed earth. Recent investigations of small sewers and pipes have shown that, due to some arching action of the earth itself, the full dead weight is not always applied to the sewer. The allowable reduction, however, seems to be of little importance until the depth of the fill is at least equal to the width of the trench and would only amount to about 25 per cent. when this depth is twice the width. The work of Marston and Anderson indicates that for depths of 10 to 15 times the width, only 30 to 40 per cent. of the load is carried by the sewer. For a sewer more than 8 ft. in width, the depth of cover will rarely exceed twice the trench width, so that the reductions are hardly worth taking into account. There must also be reasonable doubt whether the gradual settlement does not finally increase the weight on the sewers considerably above the values given.

Horizontal Pressure.—There is so much doubt as to the correct values of horizontal pressures, even for a given soil condition, and the pressures will vary so greatly in the different soils, that the designer can only attempt to make a safe guess at the correct amounts to be used.

According to Rankine's theory the intensity of horizontal pressure cannot be less than one-third of the intensity of vertical pressure for a particular depth, and in ordinary clay it is customary to consider it as one-half of the vertical. For saturated ground the earth will approach the condition of a fluid, and the horizontal and vertical pressures would be equal.

Surface Loads.—Where sewers are constructed in city streets the heaviest surface load would be the weight of a road roller, and this might be taken as 15 tons on an area of 5 sq. ft. at the surface, distributed downward along an angle of 30 deg.

with a vertical. At a depth of 10 ft. this would approximately be equal to 200 lb. per sq. ft. on an area of 11 by 15 ft., or, roughly, equivalent to an additional 2 ft. of fill. If there are railroads crossing the line of the sewer, or if it seems at all possible that such roads may be built, the sewer should be designed for locomotive loading in the same way. A fair value for this loading would be 80 tons on an area of 10 by 20 ft. at the surface. Distributed as above, this would be equivalent to about 300 lb. per sq. ft. over an area of 20 by 30 ft. at a 10-ft. depth, and would give the same pressure as 3 ft. of additional fill.

For very light covers these values would, of course, be increased, and it might even be reasonable to provide for impact, but for depths of cover for 6 ft. or more it is usually satisfactory to treat such loads as additional weight of earth and allow them to increase both the vertical and the horizontal pressures. Allowance for foundations and for piles of material may be handled in the same manner.

Combination of Loading.—For final conditions, that is, after the backfill has reached a state of settled equilibrium, the sewer will be subject to a direct combination of horizontal and vertical pressures. It should be noted that the greatest bending moments in the arch will be due to vertical loads alone. Horizontal pressures usually induce moments of the opposite kind. The combination of vertical and horizontal pressures, therefore, while increasing the direct normal compression in the arch, will give smaller bending moments than those from the vertical loads. While the stress in the arch may finally reach the values derived from a proper combination of the two classes of forces, yet it is quite common for the sewer to be subject only to pressure of one kind during the construction period. Examples of this are as follows :—

(*a*) A trench is excavated through hard clay which requires little bracing and will stand vertically for some time. The trench is backfilled with the same material. Then the full weight of the backfill may act vertically on the arch for some time before the sides of the trench finally slip and add also a horizontal pressure.

(*b*) In the example above the sides of the trench may slip in against the sewer before the backfill is placed, producing heavy horizontal pressure and bending moments of reverse character.

(*c*) A trench through soft ground is held by sheet piling. When this piling is pulled there may be an appreciable time before the earth at the sides closes in and fills the void left by the piling. During this time the vertical loads only will act.

(*d*) In the above example, if the sheet piling is drawn before the backfilling is started, the earth at the sides may move in and produce horizontal pressure with very little vertical load.

Loads of these kinds will only occur while the arch is new, possibly before the concrete has attained more than half of its normal strength If the design contains a factor of safety of 4 for combination of pressures, and the concrete is only 10 or 15 days old, the arch would be about on the point of failure for vertical loads.

It would seem, therefore, that the design should provide for vertical loads alone, or at least in combination with a very small horizontal pressure on the arch only (not against vertical side walls). This loading will be critical, and from it the dimensions of the concrete and one set of reinforcements will be determined. The arch so determined should then be designed for horizontal pressure in combination with as little vertical loads as may seem possible. From this the reverse reinforcement may be calculated. Finally, it is of interest to compute the stresses under normal combination of the two.

ARCH DESIGN.

The simplest case of arch design occurs when the sewer is built in a rock cut. In this instance that portion above the rock may be taken as an arch with fixed ends, provided that the reinforcement extends well below the rock level. Where the sewer rests on rock or other incompressible material the arch may still be treated as fixed, if sufficient mass is given to the invert to resist the overturning moment in the side walls.

If the sewer is constructed in soft or compressible soil the whole section, including the invert, should be treated as an elastic bent beam and the loading must include an upward pressure on the invert equal to the total vertical load.

A number of methods have been published for the analysis of the elastic arch. Of these the simplest is that presented in Green's "Trusses and Arches." Professor Green worked out bending moments in the parabolic arch for unit loads. He also presented constants for the semi-circular arch. Green's constants for the semi-circular arch have been extended by Mr. A. E. Lindau (*Trans. Am. Soc.* C. E. Volume 51), and put into the same tabular form as was originally given for the parabolic arch. Green's analysis is based on a constant ring thickness. It is not correct for the usual case in which the arch increases in thickness from crown to springing line, and some idea of the error involved is given in Lindau's paper. Although inaccurate, this method is very convenient, in that by its use we are able to calculate moments directly from the loading without the previous assumption of an arch thickness. For the smaller sewers, and not for all purposes, and where the variation in ring thickness is not great, it is sufficiently accurate.

In the writer's practice this method has been developed into a set of formulæ applicable to the semi-circular arch. These formulæ give the moment at each 10-degree point in terms of the mean radius of the arch and of the depth of fill over the crown. In the more important work these formulæ are used in order to determine approximate dimensions for an arch which is later to be analysed by one of the more accurate methods. As the accurate methods must be applicable to all shapes of arches and variations in thickness, it is impossible to reduce them to any very simple form.

In detailing the arch from the calculated bending moments it will usually be found advisable to use two full sets of reinforcement—that is, on the inner and outer face. If it were known positively that reverse moments could never occur—for example, if it were impossible in the case of a semi-circular arch that the horizontal force could predominate—it would be reasonable to omit a portion of one set of reinforcement, or possibly to cross one set over from the inner to the outer face; but this generally cannot be insured, and the full reinforcement should be put in, even if only as an added factor of safety and for the sake of standardisation. Another reason why the arch cannot be designed too closely is that any particular section, if multiplicity of sections is to be avoided, must be designed for variations of loading over a considerable range.

In the St. Louis work, where a considerable length of one size sewer and fairly constant soil conditions occur, it has been the practice to design a section for each 5 ft. in depth of loading and to detail these sections for soft ground foundation, for hard bottom. and for deep rock cut. A designer cannot follow too closely the calculated thickness of the arch, as some consideration must be given to the shape of the outside as well as the inside of the sewer. For example, if the sewer is to be built in a trench with vertical sides it would be found much simpler to make the outside of the sewer vertical to some point above the spring point of the arch rather than to carry a small batter all the way down to the bottom of the sewer. This is because of the fact that it would cost less to fill in the small wedge-shaped space with concrete than to attempt to place and remove outside forms in the limited space available.

There seems to be no uniformity in practice as to the longitudinal reinforcement. A certain amount of steel is usually required in this direction to properly tie in the transverse bars and $\frac{1}{2}$ or $\frac{3}{4}$ in. bars are often used on about 2-ft. sections in both faces. If the sewer is to be constructed in hot weather, and particularly in shallow cut, it might be advisable to increase the amount of longitudinal steel in order to distribute shrinkage cracks, but under other conditions this seems hardly necessary, as the range of temperatures in the completed sewer is very small, probably varying from about 40 deg. F. in winter to 70 deg. F. in summer, unless steam or hot wastes are permitted to enter.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

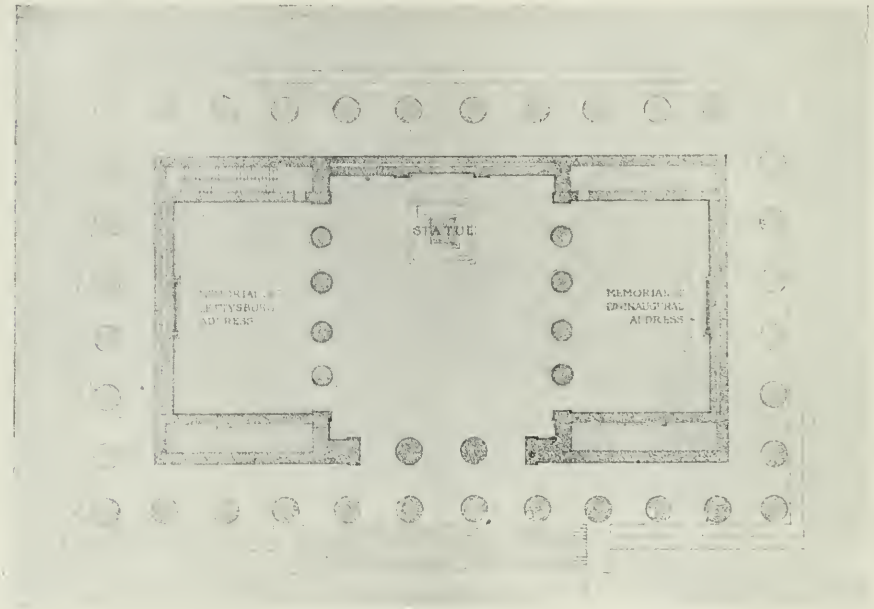
Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE CONCRETE FOUNDATIONS OF THE LINCOLN MEMORIAL, WASHINGTON, D.C.

THERE are some interesting constructional features in connection with the concrete foundations for the Lincoln Memorial, now being erected in Washington.

Below will be found a few short particulars and illustrations of this work, abstracted from an article by Capt. James A. O'Connor, Corps of Engineers, Washington, and published in "Professional Memoirs," U.S.A.

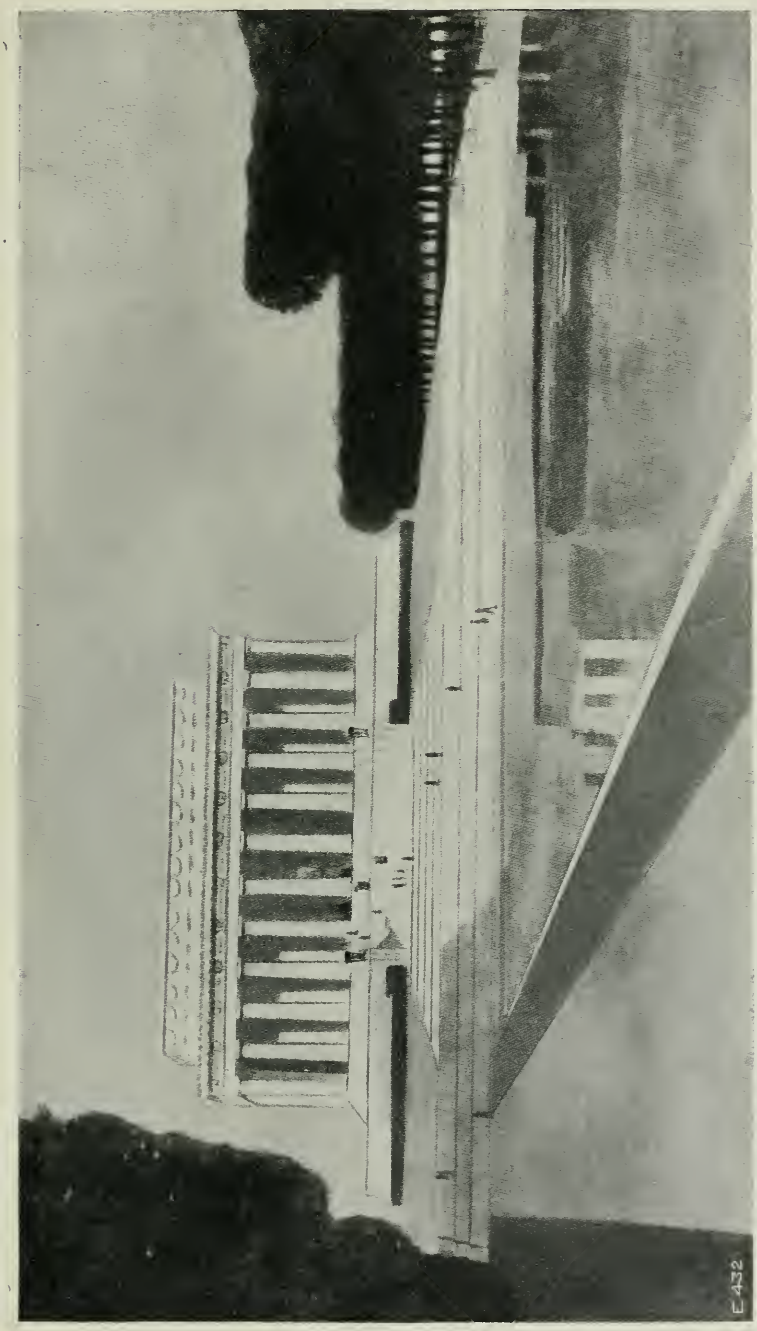
The Lincoln Memorial is situated at one end of what might be called the main axis or base line of the grand development running west from the Capitol and which is fixed by the Capitol building, the Washington Monument, and the Lincoln Memorial. Great stress was laid upon the lack of a practicable foundation, especially a foundation suitable for the massive monumental structure which was deemed necessary to fit in with the general proposed plan of the Capital City, and to represent by its dignity, grandeur, and loftiness of purpose, the character of Lincoln.



Plan of Memorial.

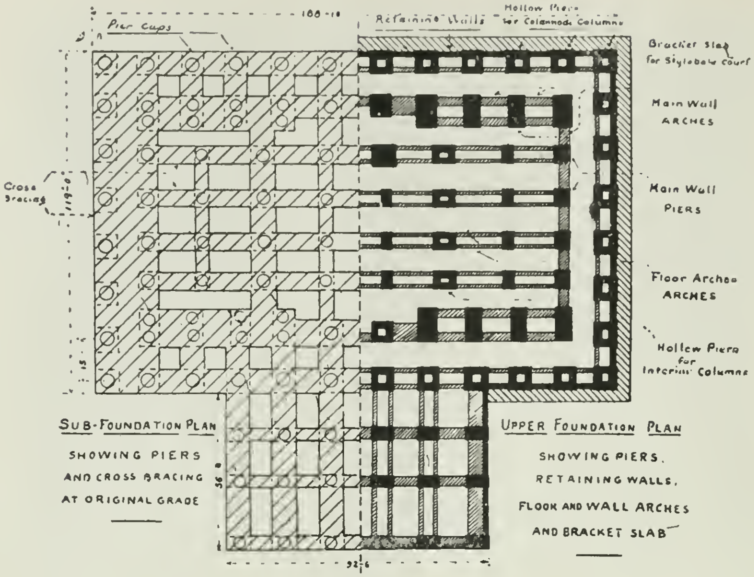
THE FOUNDATIONS FOR THE LINCOLN MEMORIAL, WASHINGTON.

The site is located about 5,000 ft. west of the Washington Monument, and is on a line with Twenty-third Street. The problem was to provide a stable foundation for a structure 204 ft. long by 134 ft. wide, with a total weight at the original grade level of approximately 50,000 tons distributed among 106 piers.



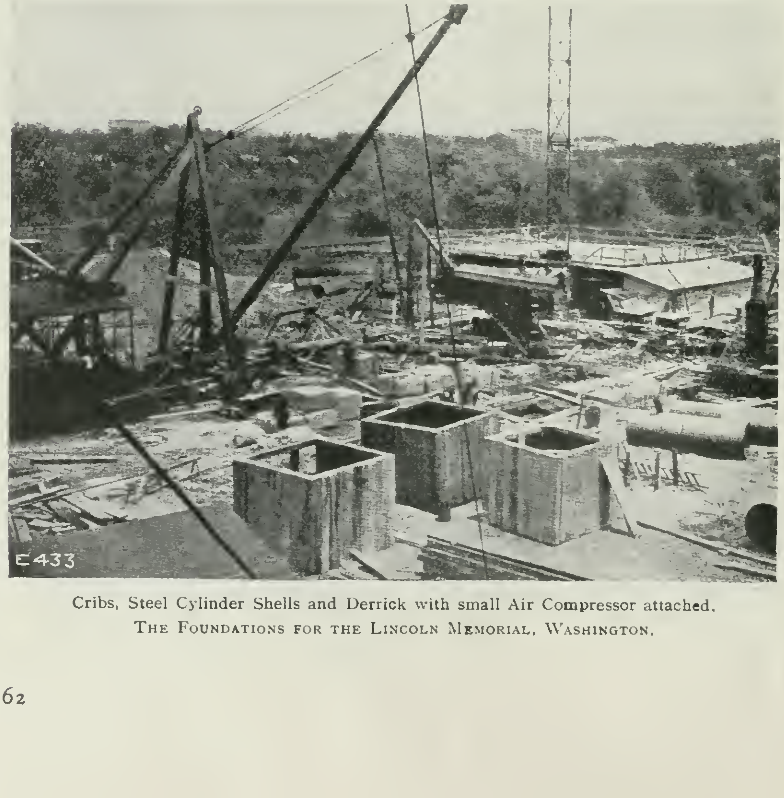
The Memorial as it will be when completed.

THE FOUNDATIONS FOR THE LINCOLN MEMORIAL, WASHINGTON.



PLAN

Showing Upper and Sub Foundation.



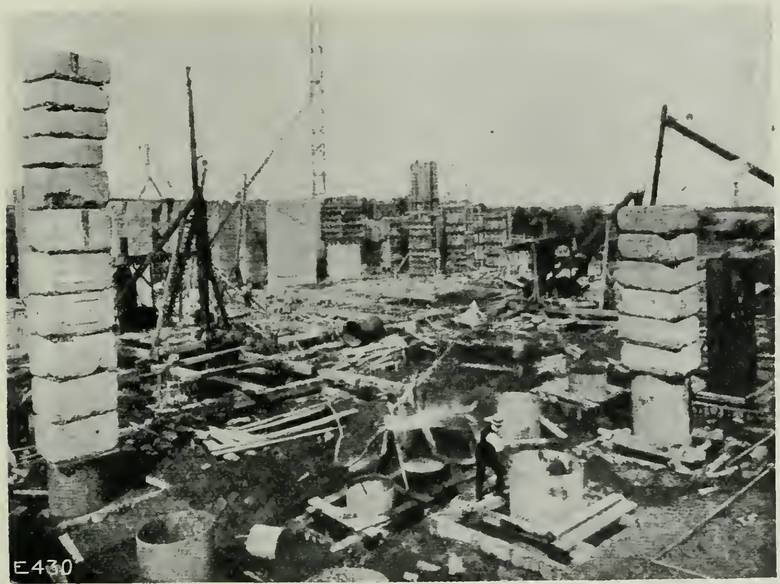
Cribs, Steel Cylinder Shells and Derrick with small Air Compressor attached.
THE FOUNDATIONS FOR THE LINCOLN MEMORIAL, WASHINGTON.

To understand more clearly the foundation problem, a brief description of the structure will be given.

It consists of a memorial hall, 84 ft. wide and 156 ft. long, surrounded by a colonnade of 36 massive columns representing the 36 States at the time of Lincoln's death. The height of the building itself is about 83 ft., and the memorial hall is divided into three sections by two rows of interior columns 50 ft. in height. The central and main section is to contain the main feature, a statue of Lincoln of heroic size, and the side sections are to contain memorial tablets of his Gettysburg speech and of his second inaugural address.

The base of the building is 45 ft. above the original grade level, and will be reached by means of terraces.

The building is of white marble. It is interesting to note that the interior lighting, in addition to that through the entrance, will be through thin marble slabs in the ceiling. Air passages are provided in the walls to reduce the condensation in the interior.



Cylinders in various stages of being sunk and Method of Loading. Upper Foundation Piers.
THE FOUNDATIONS FOR THE LINCOLN MEMORIAL, WASHINGTON.

The foundations are, for convenience, divided into two parts; the upper foundations, including the part above the original grade level (elevation 16), and the sub-foundations extending from the original grade level down to rock.

The upper foundations consist of 106 rectangular concrete piers, which vary in size from 3 by 6 ft. to 7 ft. 4 in. by 11 ft., and are 45 ft. high. The 3 by 6 ft. piers are reinforced, and the 46 piers supporting the superstructure columns are hollow, with walls 2 ft. thick. Connecting the exterior piers are reinforced concrete walls 1 ft. thick. The piers support the beams, arches, and the main floor. The concrete was a 1:2:4 gravel mixture, with the exception of the solid non-reinforced piers, which were of a 1:3:6 mixture.

The sub-foundation consists of reinforced concrete piers supporting the upper foundation piers and extending down to and 2 ft. into bed rock.

The accepted sub-foundation plan in detail is as follows:

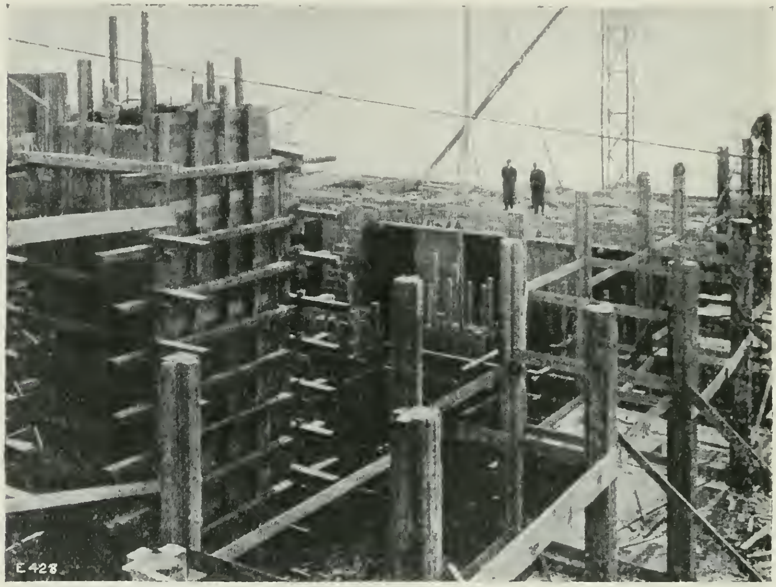
It consists of 122 reinforced concrete circular piers, which extend 2 ft. into the solid rock at the bottom and which are tied together with a cross-bracing at their tops at the original ground level. The diameter of these piers varies from 3 ft. 6 in. to 4 ft. 2 in., and they are reinforced with twelve $1\frac{1}{4}$-in. square twisted steel rods, with the exception of the piers 3 ft. 6 in. in diameter, which are reinforced with twelve 1-in. rods. The forms for the sub-foundation piers were steel cylinders, ½ in. thick for the lower 20 ft., and ⅜ in. thick for the remainder. The cylinders were sunk to rock, the earth and rock were excavated, the reinforcing steel was placed, and the cylinders were then filled with concrete. The cross-bracing at the original ground level is concrete 1 ft. thick, reinforced with ¾-in. square twisted steel rods placed 12 in. on centres, top and bottom. This cross-bracing at the top of the sub-foundation piers, together with the 2-ft. penetration of each pier into the rock, at the bottom, makes a unit of the sub-foundations.

An investigation was made of the strength of this foundation to determine its stability, which included:

The load on the sub-foundation piers;

The stability of the sub-foundations as a whole against any probable lateral pressure.

The latter included the resistance of the piers acting as unsupported columns.



Details of Pier Forms at Basement Gallery Floor Level, 25 ft. above original grade.
THE FOUNDATIONS FOR THE LINCOLN MEMORIAL, WASHINGTON.

The Load on the Sub-Foundation Piers.—The concrete in the piers is a 1 : 2 : 4 gravel mixture. Considering that there is 1 per cent. of hoop reinforcement, it is safe to assume that the ultimate crushing strength is 2,000 pounds per sq. in. The loading on the piers is such that the maximum stress is 575 pounds per sq. in., and the average is less than 500. It is therefore safe against crushing due to the weight of the building.

Construction of the Sub-Foundations.—From the deductions from the information obtained from the borings, it was fully expected that it would be necessary to use air in working below the water level. The wet clay, however, was decidedly water-tight, and the only trouble was from water that came through the porous top sand layer. The equipment included a complete air-compressor plant with two 60 h.p. locomotive type boilers, an air compressor, and an air lock. For setting the cylinders and handling the material there were two 10-ton stiff-leg skid derricks. The original plan was to excavate from the inside of the cylinders with a 2-ft. orange-peel bucket. The material was too stiff to make this plan successful, and the excavation had to be made with short-handled shovels, the material being lifted out in large buckets, for the handling of which two small derricks were later added to the equipment.

The general plan was first to make the initial excavation, then to set the cylinders and to sink them with the large derricks, and to follow up with the small derricks for the excavation from the interior of the cylinders.

The method used in sinking a cylinder was first to sink an 8 ft. by 8 ft. box or crib through the sand until the lower edge was resting in the clay.

The crib was placed in position and sunk with an orange-peel bucket. Next a hole was dug into the clay about 12 ft. deep. Guides were placed on the top and bottom timbers of the box and the first section of the cylinder, 27 ft. long, was placed. The weight of the cylinder section was sufficient to sink it into the clay and firmly fix it in position. It was then loaded, usually with five 2½-ton concrete blocks, which sank it until its top was level with the top of the box. The interior was then excavated by hand to 2 ft. or 3 ft. below the cutting edge, when the second section, 13 ft. long, was placed in position and bolted.

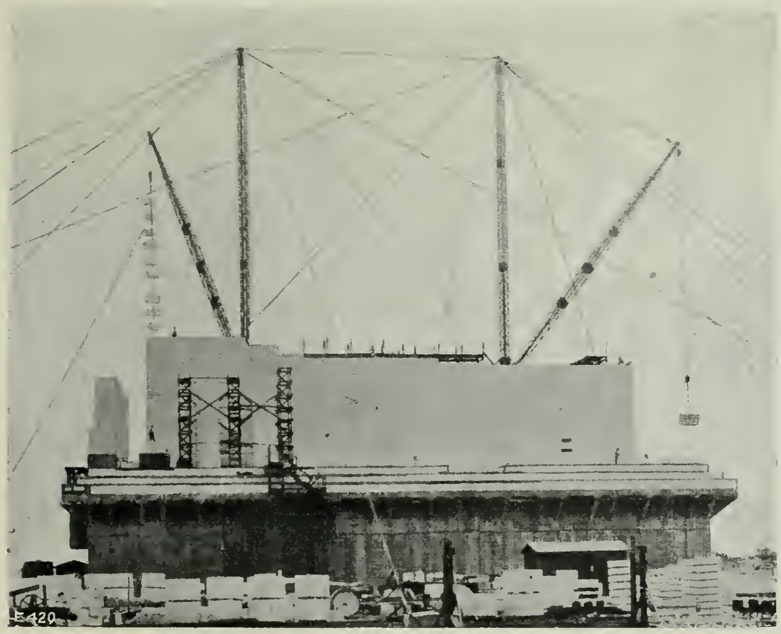
The reinforcement consisted of twelve 1¼ or 1 in. steel bars, averaging 52 ft. long, spaced and tied to a 7/16-in. spiral rod hoop reinforcing and placed by the derrick. The hoop reinforcement with the fastenings was not sufficiently rigid to prevent the assembled reinforcement from collapsing, and a method was developed in which the rods were bolted to three steel rings with a 1-in. by 6-in. section, one at each end and one in the centre. These rings were left on the assembled units until the reinforcement was finally placed and wedged in the cylinders.

The concrete, a 1 : 2 : 4 gravel mixture, was placed in the cylinders with a bottom dump-bucket holding ½ cubic yard, which was lowered by a small derrick and tripped after the previous batch had been tamped with the loaded bucket.

Construction of the Upper Foundations.—The construction of the upper foundations was similar to massive concrete work of the same character. The only unusual point was due to the fact that it was specified that certain piers be poured to a height of 37 ft. at one time.

The forms developed were adjustable to the various sizes of the piers, and withstood the pressure with very little deflection.

The walling pieces were spaced 2 ft. 6 in. on centres vertically, and the corner posts were made up in one 12-ft., two 10-ft., and one 5-ft. sections for convenience in handling and adjustment to the various heights. When the forms were removed, the top 5-ft. section was left in place to carry the beam, arch, and the floor forms.



Completed Foundations, showing part of Superstructure.
THE FOUNDATIONS FOR THE LINCOLN MEMORIAL, WASHINGTON.

CORRESPONDENCE.

Under this heading we invite correspondence.

To the Editor, CONCRETE AND CONSTRUCTIONAL ENGINEERING.

"Concrete Institute Report: Loads on Bridges."

SIR,—In the Editorial Notes which appeared in the February issue of your widely read periodical, you suggest that the Committee "should obtain an opinion from the military authorities as to what load they would wish any new bridge to carry." It may interest your readers to know that the Committee ascertained at the commencement of their labours the probable loads that would be required by the military authorities, and so recently as the 16th of the present month (March, 1916) the Director of Fortifications and Works, after considering the Report, wrote, "The classification proposals appear suitable to War Department requirements."

I am, Sir, yours, etc.,

HENRY ADAMS,

Chairman of Committee.

To the Editor, CONCRETE AND CONSTRUCTIONAL ENGINEERING.

"Torsion Stresses in Beams."

SIR,—In reply to Dr. Oscar Faber's note in your April issue with reference to my article upon the above subject, I would like to point out that what he refers to as a "slip" in my article is more a question of correct reasoning, about which there can be a difference of opinion; it is analogous to the eccentricity in a column due to an angle bracket. I am, of course, aware that the rivets in a cleat can be designed with due allowance for the shear stresses induced by twisting; in fact, I wrote what I believe to have been one of the first articles in an English journal explaining how it should be done.

It does not, however, in my opinion, follow that, because the rivets have been so designed, the twisting moment on the beam will be only that due to the reaction considered as acting down the web. The fact that some rivets pass through the web will surely send part of the twisting moment into the beam, and it is probable that the latter will be somewhere between that taken in my article and that adopted by Dr. Faber.

I quite agree with Dr. Faber that the actual stress will depend upon the angular deflection of the beam; but, as there is no simple method of determining what that is, the statement does not get us much farther.

The second part of Dr. Faber's note deals with an improved design of the cleat, with which I agree; but in my article I was not concerned with that—I was concerned only with attempting to compute the stresses caused by a cleat in very common use.

I am looking forward with interest to Dr. Faber's further article on the subject.

Yours faithfully,

EWART S. ANDREWS.

Rolls Chambers, 89, Chancery Lane, W.C.
April 12th, 1916.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Reinforced Concrete Construction. Vol. III.: Bridges and Culverts. By George A. Hool.

London: McGraw-Hill Book Co., 6 Bouverie St., E.C.
688 pp.+xxii Price 21/- net.

Contents.—Arch Bridge—Slab and Girder Bridges—Culverts—Notes on Construction Plant—Notes on Estimating—The Artistic Design of Concrete Bridges—The Construction in Detail of Several Types of Concrete Bridges—European Concrete Bridges.

This volume has been prepared by the author in conjunction with several other writers, and it is a very comprehensive treatise on arches and culverts, being divided into eight distinct parts under the above headings. The first part, which is the most important, occupies over three hundred pages, and in this the calculations and general design for various types of arch bridges are dealt with. The text commences with simple explanations of the formulæ for the deflection of curved beams which are employed in the development of arch theory, and throughout an attempt has been made to meet the needs of students by omitting intricate mathematical analyses involving the calculus. Two entirely different methods of arch analysis are presented in order that a check may be had on all arch computations. In the portion devoted to slab and girder bridges a certain amount of matter has been omitted which would otherwise be included, owing to the methods of design having been explained at length in vols. i. and ii. by the same author. This section is, however, quite comprehensive, and all the essentials of design are considered. Culverts of various types are fully explained by the author, and two useful sections follow which deal with construction plant and estimating respectively. The notes on the artistic design of concrete bridges, which have been written by Wm. J. Titus, contained in part vi., are particularly interesting, and quite the best we have seen on the subject. There is no doubt that bridge design offers the finest possible opportunity for really good work in reinforced concrete, and results can be obtained with the material which would be impossible with any other. The notes under review contain many illustrations of work executed, and the author points out the good and the bad points in these examples and his criticism is good. Some excellent work would result if these chapters were studied by designers and the principles of good work as here given followed. The two last sections are quite good and much useful information is given. The volume is well illustrated throughout and it can be thoroughly recommended to our readers.

The Reinforced Concrete Regulations of the London County Council. A Handy Guide containing the full text, with Explanatory Notes, Diagrams, and Worked Examples. By Ewart S. Andrews, B.Sc.Eng., M C.I.

Published by Messrs. B. T. Batsford, Ltd., 94, High Holborn, London. 69 pp., 7½ in. by 5 in. in cloth. Price 2s. 6d. net.

These notes and diagrams have been prepared with the aim of assisting architects and engineers in the calculations required by L.C.C. regulations.

In order to prevent any confusion arising between the regulations themselves and the explanatory notes and diagrams, the latter have been arranged in a separate section at the end of the volume, with the paragraph of the official regulations to which they relate clearly indicated.

To assist further in the rapid reading of the regulations, portions of special importance have been printed in heavy type.

The diagrams are a very valuable adjunct to the regulations, and save the price of the book in the time saved during the first day of its use.

It is one function of the regulations to lay down a definite standard of stability, but it is the proper function of authors to prepare tables and charts based upon the standards of stability demanded by law.

The regulations allow the fullest liberty in respect of the various systems of construction, proportions of concrete, and percentages of reinforcement, but it is left to the various patentees, specialists, and constructors to draw up tables suitable for their particular system and their favourite proportions of concrete and their pet percentage of steel.

When these are agreed upon, the equations in the regulations simplify down a great deal. This procedure appears to have been the obvious intention of those who were responsible for the form of the regulations.

Of course, it is up to everyone who uses a table or a chart to satisfy himself that the table or chart does really accord with the legal standard, but the scientific standing of the author and his unbiassed position are a guarantee of general reliability of any of the tables and charts prepared by him; but none of us are infallible, and a few errors occur in this book, which we hope to see corrected in later editions.

On page 44, *Fig.* 2, the smallness of the squares makes the whole diagram execrable. Such diagrams " fidget " the eyes and are a cause or an aggravation of eye-strain.

The trained eye is an excellent judge of proportional parts, and the small divisions worry the eyes beyond endurance if such a chart is much in use.

On the other hand, the diagrams on pages 52 and 53 are charmingly clear.

With regard to *Fig.* 2, on page 44, either the figures along the vertical sides of the diagrams are wrong or else the side titles are reversed, or else there is some doubt as to whether " side " or " span " should be used. In any case, all who are not already expert enough to do without that particular diagram are advised to ignore it, in case they fall into dangerous error.

The diagrams giving the values of the Resistance Moment *Qualifier* $\underset{\sim}{Q}$, in the equation $B = \underset{\sim}{Q}bd^2$, are charmingly clear and are quite the best graphs we have seen of this particular function, but having regard to the liberty we have in the selection of units, it would be better if the diagram stated that the values of $\underset{\sim}{Q}$ in the graph were in lb. per sq. in.

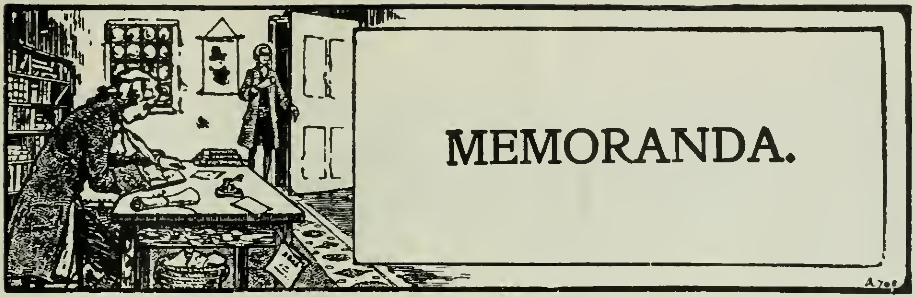
We know that fact is stated elsewhere in the book in small print, but it is suggested that it might also appear on the left-hand margin of the diagram, thus:

" Value of the Resistance Moment *Qualifier* ($\underset{\sim}{Q}$) *in lb. per sq. in.*

Then those who prefer centals, milals, kips, or tons will know what corrections to make.

There appears to be an arithmetical error in the numerical example on page 60, where the breadth of the slab is taken at 48 in. in one place and then at 60 in. later on.

The book deserves a good sale, and we know for a fact that it is being widely used both by novices and experts.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Reinforced Concrete Bridge, Mullet Creek, N.S.W.—In accordance with the policy now being adopted by the Public Works Department, New South Wales, of substituting reinforced concrete for timber in road bridges, a new structure has just been completed over Mullet Creek, on the main south coast road, near Dapto.

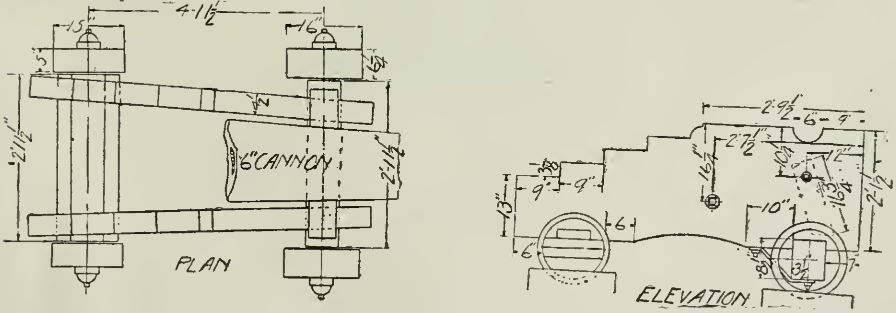
It consists of four spans of 30 ft. centres and two end spans of 12 ft. centres. The roadway is 18 ft. wide between the kerbs, and covered with tarred metal over the concrete slab. The abutments consist of two concrete columns on extended footings surrounded with dry rubble walling to retain the earthwork of approaches. The main piles are supported on timber piles 30 ft. long in groups of four, driven to about 40 ft. below water level.

Each group of piles, two to each pier, are surrounded with reinforced concrete cylinders filled with concrete reaching from about 14 ft. below to above water level. On these rest two octagonal columns, braced with a concrete web carrying the main beams of the superstructure. This consists of a floor slab 12 in. thick with two ribs spaced 12 ft. centres, the outer portion of slab acting as a cantilever.

The spans are not continuous, a joint being provided over each pier. The reinforcement throughout is of round steel bars with hooked ends.

The bridge was designed by the Public Works Department and constructed under contract by the State Monier Pipe and Reinforced Concrete Works. The cost of the bridge was about £2,900, which included £135 for removal of old bridge, bank protection, and provision for foot traffic.

Gun Carriages of Concrete.—At the base of Brock's monument at Queenstown Heights, in Queen Victoria Niagara Falls Park, are five 6-in. ship's cannon, bearing the mark of the old Scottish gun-maker, Carron, and the date 1807. The oak carriages having become unsafe, it was decided to duplicate them, but owing to the prohibitive cost of oak, the Park Superintendent decided that the carriages could be made by using concrete, not only at a considerable saving in first cost, but at a continued saving due to low maintenance and permanence. The accompanying diagrams make the construction clear. This use of concrete is suggestive to those in charge of parks, where a little thought will often result in a saving in cost and in increased



Details of Concrete Gun Carriages.

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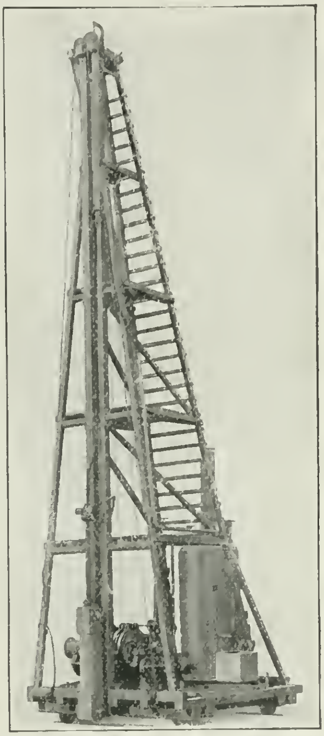

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permanence. The concrete carriages are said to have cost slightly less than half the price quoted for oak.—From *Concrete, U.S.A.*

The Niger Bridge (South Channel).—The bridge was tested in January with very satisfactory results, and is opened for traffic for a maximum speed, under ordinary circumstances, of 25 miles an hour.

The bridge consists of seven spans of 183 ft. between centres of bearings, with viaducts of three concrete arches at each end. The total length is 509 yards, and total weight of girders about 1,020 tons. There are six piers in the river, of which four were sunk in sand to 77 ft. below low water level; one was built on rock 12 ft. under water at low river, and the other was sunk through sand until it rested near one end on a ridge of rock 25 ft. below level of river bed.

Preliminary borings had given an erroneous idea of the lie of the rock, which was found actually to descend in steps to a depth of 57 ft. below river bed. Steel sheet piling was driven into rock all round the pier.

The space under the pier was divided by steel shuttering into three sections, to which access was obtained through the dredging holes in the pier. Sand was excavated down to rock and concrete filled into underside of caisson, each section having to be completed before the next was begun. All this difficult work connected with the underpinning was done by divers and occupied fully two years. The total time occupied in building the bridge has been a little under five years.

The total cost will be about £130,000, the original estimate, including approaches, being £92,158.

The Omanawa Falls Hydro-Electric Scheme, N.Z.—Concrete and reinforced concrete have entered to some extent into the structures in connection with this scheme. Omanawa Falls lie about 14 miles to the south of Tauranga Harbour and are beautifully situated. So as to avoid undue interference with the beautiful scenery the engineers hid all their work in the heart of the rock. The falls are peculiarly adapted for power development.

The power-house measures 50 ft. by 19 ft., and extends upwards 18 ft. from the floor in a parabolic arch. Part of the floor is a reinforced concrete arch. The outer end of the cave is closed flush with the rock face by a concrete wall, having window and door, and within the walls are lined with 3 in. of concrete to a height of 8 ft. from the floor.

There is also a sub-station built entirely in reinforced concrete with walls 4 in. thick.

New Technical Institute, Cardiff.—All the floors in this building are of 6 in. concrete between rolled steel joists; these and the steel roof principals have been supplied by Messrs. A. D. Dawnay and Sons, of London and Cardiff.

The main staircase is constructed of reinforced concrete on the Hennebique system.

PROPOSED WORKS.

South Australia.—Details of the items authorised by the South Australian Public Purposes Loan Bill show that included in the expenditure provided for is £272,000 for the improvement of harbours at Port Adelaide, Port Pirie, and at outports, and £500,000 for the River Murray improvement; £1,465,000 for waterworks at Adelaide, Baroota, Country, Beetaloo, Bundaleer, Barossa, Millbrook, Warren, and Pekina Creek; and £42,000 for jetties and lighthouses.

Chile. — Messrs. Gibbs and Co. have been granted permission by the Government to construct a wharf at the Port of Mejillones, and must present plans and estimates within six months.

Baku. — The town of Baku, Russia, has been authorised by Imperial Decree to issue a bond loan for £1,266,700 for the completion of the Baku-Shollarski waterworks scheme.

Seaham. — Plans for a new graving dock have been prepared by the Seaham Harbour Dock Co., but the work is not likely to be put in hand until after the war is over.

Gravesend.— The Corporation are approaching the Port of London Authority in regard to a proposal to construct a deep-water wharf at Gravesend.

Keighley. — It is proposed by the Waterworks Committee of the Corporation that concrete be substituted for clay in the core wall of the embankment of the new Lower Laithe reservoir at an extra cost of £15,000.

Glasgow. — The Dean of Guild Court have passed plans for an electric power station at the Blochairn Ironworks for the Steel Co. of Scotland.

Vancouver.— It is proposed to build a dry dock at Vancouver, British Columbia, which, together with shipbuilding plant, is estimated to cost £1,250,000.

Swanscombe. —In connection with the building of the proposed new river jetty at the outfall works of the West Kent Sewerage Board, it has been decided to admit tenders for a reinforced concrete structure.

Western Australia.—The estimates of expenditure of the Government of Western Australia provide for the following amongst other works: Electric power station at East Perth, £182,000; harbour improvement works at Albany, Bunbury, Fremantle, etc., £140,100; jetty works, £17,000; water supply and sewerage at various towns, £337,120.

Argentina.—The State Railways Administration will shortly present plans for the construction of viaducts and bridges over the Rio Salado, on the Dean Funes-Laguna Paiva line of the Central Northern Railway.

Bexley. — Concrete coal bunkers are to be provided at the generating station by the Urban District Council.

Belfast Waterworks Scheme. — The Belfast Waterworks Commissioners have decided to proceed with the second portion of the Mourne water scheme, which includes the construction of the Silent Valley storage reservoir, in the Kilkeel Valley. The reservoir will have a storage capacity of three thousand million gallons, and when completed will form one of the largest artificial reservoirs in the United Kingdom.

Winnipeg Water Supply.—Winnipeg, Manitoba, is now engaged in the work of bringing its water supply by gravitation from Shoal Lake, a distance of about a hundred miles. The conduit of the Greater Winnipeg Water District is nearly ninety-five miles long, and nearly eighty-five miles of it is in concrete. At the lower end some five miles of the conduit is a reinforced concrete circular section. At the crossing of the Brokenhead River there is about two and a half miles of circular reinforced concrete conduit.

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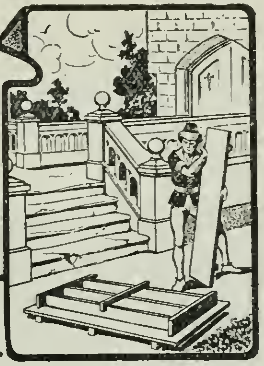


CONCRETE FENCE POSTS.

II.

In continuation of the particulars in our last supplement, we give below some additional notes regarding the making of concrete fence posts.—ED.

MIXING THE CONCRETE.

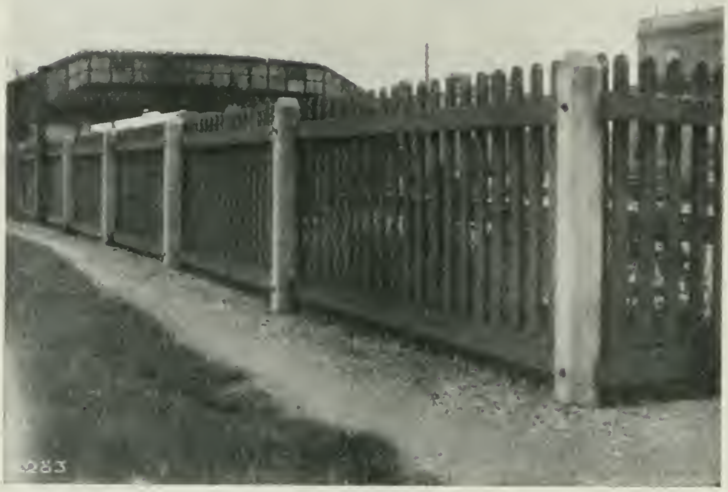
The Mixing Board.—The size of the mixing board depends on the number of men employed in this work and on the amount of room available for placing the board in position. Sometimes a tight and even floor in a building may be used. The steel sheet from the platform of an old self-binder may be used for a mixing board, but the larger the board the more convenient it is. For two men mixing, the board should be 8 ft. by 12 ft.; for four men, 14 ft. by 14 ft.

Reinforced Concrete Fence Posts.

The first size is usually large enough for making posts. It should be built of 1-in. match boards, free from knots, drawn tightly together and placed the short way of the platform, so that the mixers may shovel with the cracks and not against them. The framework should consist of four pieces of 2 in. by 4 in., laid the long way, and with the two outside ones of sufficient length to afford handles for carrying. The location for the board should be fixed before the sand, stone, and gravel are unloaded. A level spot with sufficient open space convenient to the work, and, if possible, near the water supply, should be chosen. Much hard labour can be saved by locating the mixing board lower than the water tank and by siphoning the water through a garden hose to a barrel or other receptacle at the mixing board. The board should be raised on blocks until it is level, so that under the weight of concrete it will not sag in the middle. If water is added gradually, as it should be, there will be little liquid grouting to run. It is best, however, to nail a 2-in. by 2-in. strip or a piece of 2-in. by 4-in. scantling around the edges of the board.

Runways.—If, in wheeling the materials, runways are necessary, they should be built so that they will be smooth and strong. Should the runs be over 2 ft. above the ground, 20 in. is none too great for their width. The speed of the work depends upon the rate of moving the materials and concrete.

Tools.—One great advantage in using concrete is that it can be made with the investment of very little money in special tools. If the few required are not already at



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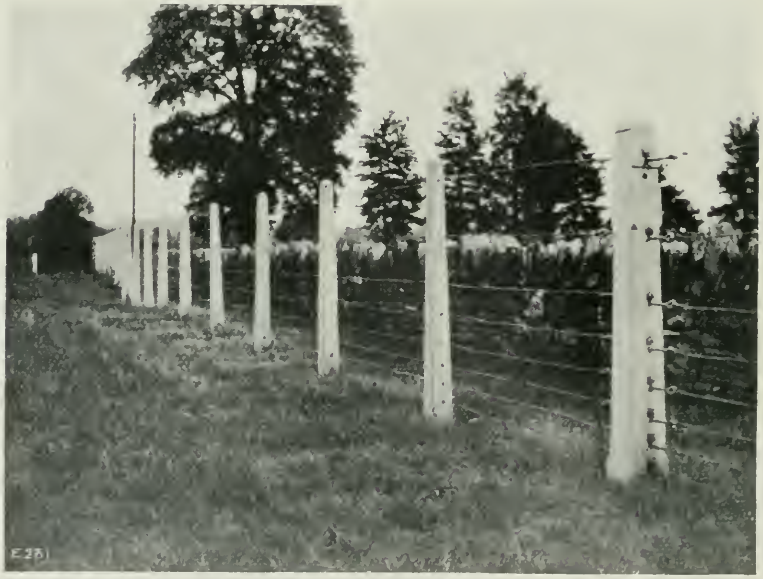
Platform Fencing Posts.

The Great Western Railway produce some 40,000 fencing posts annually, which is equal to about 45 miles.

Platform fence posts, reinforced, are well worthy of attention, as they give a good foundation for the wood paled fence on station platforms. They are, of course, free from decay, and that at least doubles the life of the wood portion, and, being framed as shown, any length of the timber can be readily removed by taking out two bolts.



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Reinforced Concrete Fencing.

FENCE POSTS ON OUR RAILWAYS.

hand for other purposes, the new ones will serve in many different lines after the concrete is finished. For mixing, it is necessary to have from two to four square-pointed, short-handled "paddy" shovels, size No. 3. A couple of wheelbarrows with steel trays, and with a capacity of 2 cu. ft., are convenient for moving the sand, stone, and concrete. If wooden moulds are used, a metallic sidewalk "edger," with a curve of three-eighths of an inch in the radius, will make neat corners. A corner trowel, or even an ordinary trowel, will answer the same purpose fairly well. Screens may be made by nailing $\frac{1}{4}$-in. and $\frac{1}{2}$-in. mesh wire screening, $2\frac{1}{2}$ ft. by 5 ft., to frames made of 2-in. by 4-in. timber.

Reinforced Concrete Fence Posts on the London & North Western Railway.

The Measuring Box.—Since construction with concrete is so easy, many persons are careless about the exact proportions of the cement, sand, and gravel or crushed stone to be used in its composition, but this is a very important point. The bottomless box with handles attached is a very useful article for this purpose. For posts, a convenient measuring unit is a box with an open bottom 12 in. by $14\frac{3}{8}$ in. and 10 in. deep, measured on the inside. This box, filled to the top with the loose material and smoothed level, contains practically 1 cu. ft. The inches in height may be marked with brass tacks. Then, since each inch in height represents one-tenth of a cubic foot, the measurements are easy. If, on account of its size, the use of this box would be too slow for measuring the sand and gravel, larger boxes or wheelbarrows may be gauged and used, or other boxes may be made on the same principle. It is a very poor practice to count shovelfuls, as it produces unsatisfactory and even dangerous results.

Making a Six-Post Batch.—The following table gives approximate quantities for a batch of concrete sufficiently large to make six posts 7 ft. long and of the sizes named in the table. The quantities may be increased in like proportion and any desired number of posts may be made. The first of the two lines of figures given for each of the three grades, heavy, medium, and light, indicates the proportions to be used when the sand is screened from the gravel. The second line gives the proportions when "bank-run" gravel is used; that is, gravel dug directly from a bank without screening the sand. In this case 1 part of cement to 4 parts of the mixture of sand and gravel should be used.

QUANTITIES OF MATERIAL AND RESULTING AMOUNT OF CONCRETE FOR A SIX-POST BATCH.

Triangular Posts—Length, 7 feet.

Size of Post.	Proportions of Materials by Parts, Measured in Volume.			Materials in Cubic Feet, Measured Loose.			Concrete Tamped, Cubic Feet.	Water for Mixing, Gallons.
	Cement.	Sand.	Gravel or Rock.	Cement.	Sand.	Stone or Gravel.		
Heavy ...	1	2	4	1·4	2·8	5·6	6·2	11
	1	—	4	1·5	—	6·0	6·2	11
Medium ...	1	2	4	1·3	2·6	5·2	5·5	10
	1	—	4	1·4	—	5·6	5·5	10
Light	1	2	4	1·1	2·2	4·4	4·8	9
	1	—	4	1·2	—	4·8	4·8	9

Rectangular Posts—Length, 7 feet.

Size of Post.	Cement.	Sand.	Gravel or Rock.	Cement.	Sand.	Stone or Gravel.	Concrete Tamped, Cubic Feet.	Water for Mixing, Gallons.
Straight, 5 by 5	1	2	4	1·7	3·4	6·8	7·3	13
	1	—	4	1·8	—	7·2	7·3	13
Taper on two sides, 4½ by 6, 4½ by 4½	1	2	4	1·6	3·2	6·4	6·9	12
	1	—	4	1·7	—	6·8	6·9	12
Full taper, 5 by 6, 4 by 3 ...	1	2	4	1·5	3·0	6·0	6·7	12
	1	—	4	1·6	—	6·4	6·7	12

NOTE.—This depends on atmospheric conditions and also whether the sand is from the pit or river.

Proportioning the Ingredients.—On account of the variations in the size of the sand grains and in the unfilled spaces between the particles of sand, stone, and gravel, the quantities of concrete made according to the proportions above may be greater or less than those stated in the tables. For the same reason the quantities of water may or may not be sufficient to make the concrete wet enough. Such matters, with the experience gained through making a few batches, may be easily adjusted. Water should always be measured by the bucket to have uniform results.

Different pockets of sand and gravel and different " crusher-run " stone vary in size and consequently in the unfilled spaces or voids between the grains or pieces. This variation, in theory, calls for varying quantities of cement, but the methods of determining the exact amount of these unfilled spaces are so complicated and so open to mistakes that, with cement at its present low price, it is cheapest in the long run to adopt proportions or mixtures which are rich enough to guarantee a well-made, strong post. If unscreened " bank-run " gravel is decided upon, it should be used in the proportion of 1 part of cement to 4 parts of gravel. For crushed stone or screened gravel (which is much better than " bank-run " gravel), the concrete should be used in the proportion of 1 part of cement, 2 parts of sand, and 4 parts of rock or gravel. All measurements should be made with the material poured loosely into the measuring box, and the box, when full, should be levelled smooth.

The amount of moisture in the sand, gravel, and stone varies so much with weather conditions that the quantity of water for a cubic foot of concrete cannot be fixed exactly. During the mixing of the cement with the sand and rock sufficient water should be used for the concrete to be wet enough, when the mixing is complete, to tremble under a blow from the shovel and to run into the moulds. This amount of water causes a rich mortar to flow to the outside of the post and insures a smooth finish. A force pump and hose afford a convenient means of conveying water to the work. Often by locating the mixing board lower than the water tank water may be siphoned through a garden hose to the board.

Mixing "Bank-run" Gravel.—For concrete from unscreened " bank-run " gravel, one-half of the amount of gravel required for a batch of posts should be spread out in oblong shape; and upon this should be evenly distributed, first the full amount of cement, and then the remainder of the gravel. Two men facing each other and at the same end of the batch (and, if necessary, two at the other end), with square-pointed " paddy " shovels, turn the dry cement and gravel with a " flopping," dragging stroke. By timing their strokes, the mixers can cause their shovels to meet regularly at the middle, which insures the complete mixing of all the materials. For a thoroughly mixed concrete, no definite number of turnings can be fixed, but the shovelling should be continued until the cement no longer shows in streaks or until the mixture has a uniform colour. Skilful concrete turners do not lift the shovel from the board and " flop " over its contents as though they were turning " flapjacks," but by gradually turning the shovel and at the same time dragging the stroke they completely mix the dry cement and gravel in two turnings. When the scattered materials around the edges have been thrown upon the pile it is cut open and, using a sprinkler—a sprinkler bucket or a hose with spray attachment—about three-fourths of the water required is added. Water dashed from buckets or from the ordinary nozzle of a hose causes a waste of cement. The mixture is again turned and cut open as before. Then the remaining one-fourth of the water is added and the mixture is turned again. With careful workmen the concrete should now be well mixed, but if it shows dry spots it must be turned once more. After this the concrete should be shovelled into a compact ridge, ready to be wheeled away to the moulds or to be shovelled into them. The mixing board should be thoroughly cleaned at the close of each day's work. Persons who intend to make the manufacture of posts a business will do well to invest in a good power mixer.

Mixing Crushed Rock or Screened Gravel.—In general, where crushed rock or screened gravel is used, the mixing is very similar to that of " bank-run " gravel. The full amount of sand is spread out upon the board and upon it the necessary cement is evenly distributed. The whole is turned dry until the cement no longer shows in streaks and the colour of the batch is uniform. The mixture is then spread out flat, just as the sand was, and upon it the crushed rock or screened gravel is distributed evenly. Three-fourths of the required water is added and the mixing is continued as for mixing " bank-run " gravel. In dry, hot weather it is a good plan to throw water on the pile of crushed rock before mixing.

CONCRETE POSTS.

Moulding.—After the moulds, which, as a rule, lie flat, have been oiled or soaped, the concrete should be placed in them at once. If, for any reason, the concrete stands thirty minutes after mixing, it should be thrown away and a new batch mixed, for cement, if it has once partially set, makes weak, dangerous concrete, even though it is retempered by turning or adding water. After the moulds are filled evenly to the depth of three-fourths of an inch or 1 in., according to the spacing of the reinforcing rods or wires, the reinforcement should be laid in, properly spaced by means of at least three " fool-proof " wire spacers. The concrete should then be poured in until the moulds are filled within three-fourths of an inch or 1 in. of the top, when the remaining reinforcement is fitted in place in the manner described above and the moulds are completely filled. To render the concrete more compact a crowbar or a pinch bar should be placed under each corner of the mould successively and moved up and down quickly. This vibration makes the concrete more compact by shaking out the air bubbles, but there will be very few of these bubbles if the concrete is sufficiently mixed to proper consistency. If desired, the exposed corners of the post may be bevelled with an " edger," and the open face given a neat finish by using a trowel immediately after the surface water has been absorbed and before the concrete has become too hard.

If wooden moulds are used they should be well soaked in water, so that the green concrete will not cause them to swell and thus crack the posts.

The wind, the hot sunshine, and the frost are destructive to concrete; and while it is an easy matter to protect the post from the first two agents, it is best to do no concrete work when the thermometer is below the freezing point, unless inside a building.

There is another method which is now being used for making concrete fencing posts. It is the same principle as employed in making concrete blocks. This is the " semi-dry " principle, which enables the moulds to be removed as soon as the article is made, and thus letting the mould be used continually.

The mixture, after being mixed dry, is wetted only sufficiently so as to make it hold together when it is tamped. The posts are reinforced in exactly the same way as described before, and each layer is tamped. Care must be taken so as to ensure the adhesion of one layer to the other. To make sure of this each layer should be scratched with a tool called a scratcher, as illustrated. After the posts have been made from eighteen to twenty-four hours they are watered well, and this is continued each day for ten days. With this method the same mould can be used continually, and if the corners of the posts are rounded or champhered a strip of wood may be placed in the bottom corners of the mould, and these can be drawn out after the posts are made. The top edges are taken off with the edging tool.

Curing. — It is a great mistake to believe that when the moulding is done a concrete post is finished. The quality of the post must be determined by curing. The green post should be left in the mould until thoroughly hardened; that is, usually for two or three days. For square or nearly square posts the moulds proper may then be removed and used on another bottom board, but the posts must stay on their bottom board in the shade and must not be disturbed for at least a week or ten days. Posts in triangular moulds may be carried out, each in its own mould, after from five to seven days, and the post may be gently slid from its mould to a smooth floor covered evenly with a cushion of sand. While green the strain of lifting, or even a slight jar, will cause cracks, sometimes invisible, which greatly weaken the post. During the first two days of the life of a post it must be kept wet and covered with canvas, burlap, carpet, or any clean material. Sand will serve after the concrete has become hard, but manure will stain green concrete and otherwise affect it. The sprinkling should be continued up to the eighth day. After the tenth day, if the space is needed, the post may, with care, be placed on end in the same manner that wooden fence rails were formerly piled. A drop of only 6 inches often breaks a green post. The jar in hauling to the field over rough, frozen roads or in a wagon bed with a very uneven bottom has seriously injured posts which were not well seasoned. Concrete posts gain rapidly in strength for the period of one year; they should, therefore, be made as long as possible before it is necessary to set them in the fence. No post should be used until it is at least 3 months old, and, to meet any contingency, a supply of well-seasoned posts should be kept on hand.

Figs. 2 and 3. Reinforced Concrete Fence Posts at West Mill, Brentford.

ERECTING THE FENCE.

Setting the Posts.—Experience has taught that, with regard to stringers and joists, in order to get the greatest strength from the timber, one should place the beam with the narrow side against the load and with the depth extending in the same direction as the pressure. Likewise, posts should be placed so that the narrow side will support the wire. This will give the greatest resistance to breakage from animals rubbing against them or trying to get through the fence between the posts. The depth to which posts should be set varies with the character of the soil. Seven-foot posts are usually set from 2½ ft. to 2 ft. 8 in. deep. The earth about the post should be thoroughly compacted by tamping.

It is also a good plan when erecting concrete fencing posts to concrete the feet in with some weak concrete gauged 6 or 7 to 1. As the fencing posts of this type are of such a permanent nature it pays to erect the fence in such a manner as to make it a substantial and permanent fence. If this is done the post can be 6 in. less in the ground, as the concrete around the post takes a better strain than earth or mould rammed round them.

4-FT. FENCE POSTS 12 FT. APART.

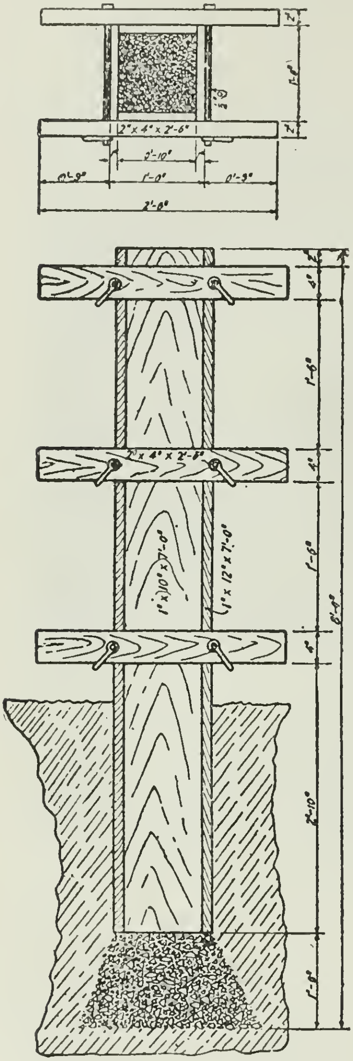
Stretching the Fencing.—Good tools for stretching wire fencing may be found in almost any fence company's catalogue. Stretchers should be such as to be easily operated by one man. They usually consist of two heavy chains, one of which is fastened to a post at the corner or brace in the fence and the other by means of a large hook to the wooden clamp which holds the loose fencing. The stretcher proper, operated by a lever, is the connecting link between the chains. By working the lever back and forth, dogs reach out, grasp, and draw in link after link of the chain, and thus tighten the fence. The best stretchers are also automatic in releasing the wire. Owing to the great force used in stretching fencing, it is advisable from the standpoint of safety to purchase stretchers with automatic releases. There are many good automatic single-wire stretchers on the market.

Line Anchors.—Concrete posts, by their weight, serve to hold fences down in the gullies of hill country. Sometimes in such places and occasionally under other conditions the wire fencing must by some means be staked to the ground to prevent small animals from going under it. This may be accomplished either by digging a hole under the fence, filling it with concrete, and embedding a tie wire in the concrete, or by burying a block of concrete around which the tie wire has been placed. After the concrete has set the fence may be made secure by attaching the tie wire to the heavy lower wire of the fencing.

MISCELLANEOUS POSTS WHICH MAY BE MADE OF CONCRETE.

Concrete posts are used for many other purposes than line posts. The sizes are slightly different, but the principles and general lines of design are the same.

Corner Posts.—Corner posts are generally made with square ends, 8 in. by 8 in., 10 in. by 10 in., or 10 in. by 12 in., and without taper. Heavier reinforcement is used and should be increased in amount by placing extra pieces on all four sides either at the middle or one-third points. The wire may be drawn around the post or holes may be made through it by placing greased iron rods at the proper places in the green concrete and turning them about occasionally so that the concrete will not set to them. A short piece of pipe may be placed through the mould and left in the post in order to provide a hole. Through these holes the strands of wire may be stretched and some tightening device may then be used. The post should be thoroughly cured before being strained by holding a tightly stretched fence.



METHOD OF CONSTRUCTING BRACKET FOR BRACING POSTS.

Bracing Posts and Braces.—Bracing posts should be placed frequently in the fence line. A mortise for inserting a brace may be made in the upper end by temporarily placing a block of the desired dimensions in the green post. This operation requires considerable skill to prevent ruining the post. Some persons prefer making an offset or bracket on the post. Others mould the post and brace together at the same time.

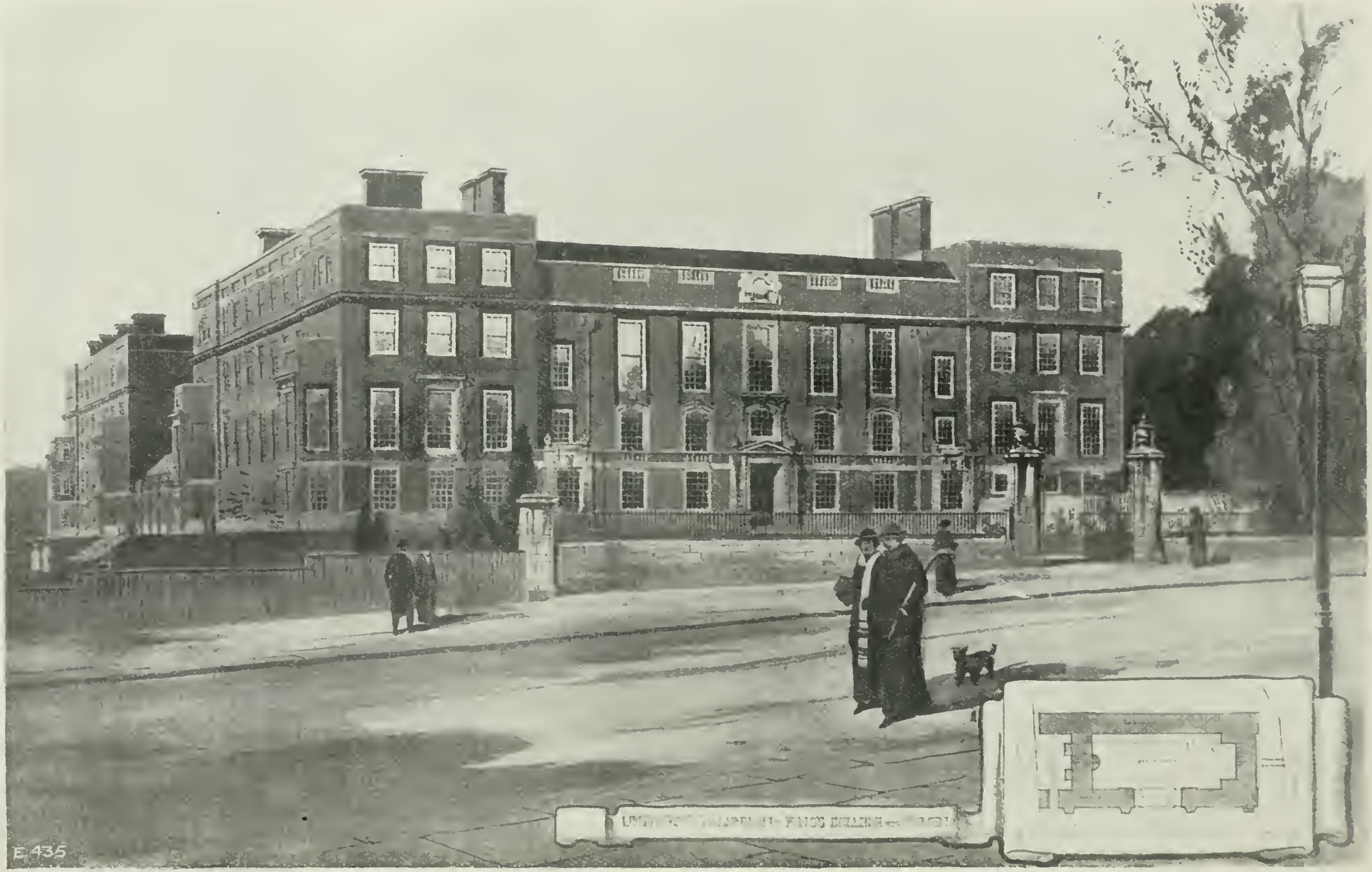
Braces are made and reinforced like line posts. The ends must be moulded to a bevel in order to fit the offset or bracket in the post. The wire brace is commonly used, but sudden strains are liable to crack the top of the line post to which the wire is fastened. Another brace between the first and second line posts and slanting in the same direction as the concrete brace will remove such danger. A mass of concrete run around the ground end of the brace will fix it securely.

Gate Posts and Hitching Posts.—Gate posts are made in the same manner as corner posts. Hanging is accomplished by using a hinge with a clamp strap which entirely encircles the post. Fasteners are attached in the same way. Holes for bolt hinges are sometimes made in the post during the moulding. Large iron washers should then be placed between the post and the nut. If a hole is desired for a fastener, the hole should first be made by inserting a piece of gas pipe in the green concrete.

Hitching posts are merely line posts. Wrought-iron clamp straps make better attachments for holding the rings than holes through the post, which weaken it.

Vineyard and Arbour Posts.—As plenty of gravel is usually found in sections where grapes are grown, concrete posts are very convenient in the culture of grapes. A light line post will serve the purpose. If wire or an iron piece is not used to support the vines, an offset or bracket should be made on the post to hold the cross arm. The cross arm may also be made of concrete. Some growers prefer to erect a light line fence, using smooth wire from post to post as a means of supporting the vines.

Arbour posts are constructed in the same manner as vineyard posts. The skeleton work may also be made of concrete.



KING'S COLLEGE FOR WOMEN, CAMPDEN HILL, KENSINGTON.
(*For description, see page 283.*)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XI. No. 6. LONDON, JUNE, 1916.

EDITORIAL NOTES.

THE CONCRETE INSTITUTE.—ANNUAL GENERAL MEETING.

THE Concrete Institute, at its annual general meeting, received the report of its Council for the session 1915-16.

The report shows a record of useful work done, particularly in the direction of the presentation of technical papers and the operations of its subcommittees.

The Institute is to be congratulated on having kept things together during the war period and to have continued its consideration of matters within the purview of the sub-committees, and also to have interested its members in the very valuable contributions to the Transactions of the Institute.

The only thing we miss in this report is any active co-operation in war emergency work, which has been such an excellent feature in the majority of the great societies and institutions associated with the technical professions. We would suggest that there are various openings of a useful character if the Council and its staff had been able to accord sufficient time to the matter.

With the close of the current session Professor Adams's tenure of office as president comes to a close. His term of office has been an exceptionally difficult one, starting at a period of intense controversy within the ranks of the Institute and then continuing during a period of the war, when special circumstances and conditions naturally made the technical work of the Institute more difficult. The war emergency, however, was wisely used by the president to drop, entirely, all controversial aspects in the general administration and policy of the Institute, and the feeling that ran high at the commencement of his tenure of office was smoothed over and temporarily hidden.

All agree that, under very trying circumstances, Professor Adams has held the chair of president with dignity and equity, and if circumstances prevented any great development of the Institute, he held the reins of power in a manner that did him credit, and he will be leaving the chair with the good wishes of all the members—of those who disagreed with his policy originally and those who supported his views.

Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., has now been elected as president. He was one of the original active members of the Institute in the days of its formation, and his election is the more appropriate as his work in cement, concrete, and reinforced concrete is well known to the technical professions, and his knowledge and experience in these matters will stand the Institute in good stead.

We wish Mr. Wentworth-Sheilds every possible success during his tenure of office.

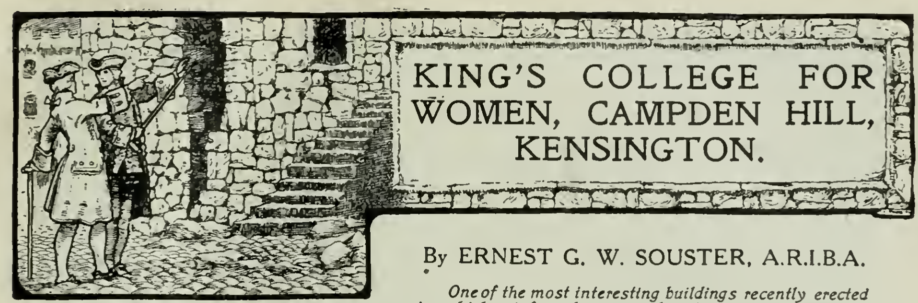
CONCRETE *v.* TIMBER.

Publicity has been widely given to the advent of a large number of Canadian lumbermen busily engaged in felling trees in the United Kingdom. Their patriotic endeavours are most welcome and their services will be invaluable during the war emergency; but it would be well if the authorities properly realised that there are now many excellent substitutes for timber. The concrete post, the concrete beam, the concrete pit prop are invaluable, inasmuch as they are not only inexpensive, but involve only a small expenditure in maintenance; all manner of shoring, abutment work, and the like can be equally well done with concrete as with timber, and, as a rule, more usefully and economically. The application of concrete in the erection of hutments is well illustrated in our current issue.

It is regrettable that so many of our authorities do not seem to realise that the war emergency should be utilised for the introduction of improved and economical means and methods.

Concrete and cement are materials so readily adaptable to innumerable purposes that full advantage should be made of them, and the timber of the country should be conserved as far as possible.

We throw out the suggestion to those who are in authority (and practically every Government department is concerned) that a little wider vision in matters of this kind would be useful in this period of war economy. There are many advantages in cement, concrete and reinforced concrete which are not yet properly realised in this country by those who direct the expenditure of money in the public interest.



KING'S COLLEGE FOR WOMEN, CAMPDEN HILL, KENSINGTON.

By ERNEST G. W. SOUSTER, A.R.I.B.A.

One of the most interesting buildings recently erected in which reinforced concrete has been extensively used is the above building, of which some particulars are given in the following article.—ED.

One of the outstanding features of the past few years has been the ever-increasing interest given to the wider education of women, and the present war has opened up a still greater field for their activities. This building therefore possesses great interest in being the most up-to-date example of a structure entirely devoted to the teaching of household and social science and such cognate subjects.

The buildings have been erected on a site at Campden Hill, which until a short time ago formed the grounds of Blundell Lodge. A site in a neighbourhood rich in historic memories is eminently suited for an educational establishment, and, as the grounds cover 2½ acres, ample space is provided for tennis courts, gardens, and outdoor recreations.

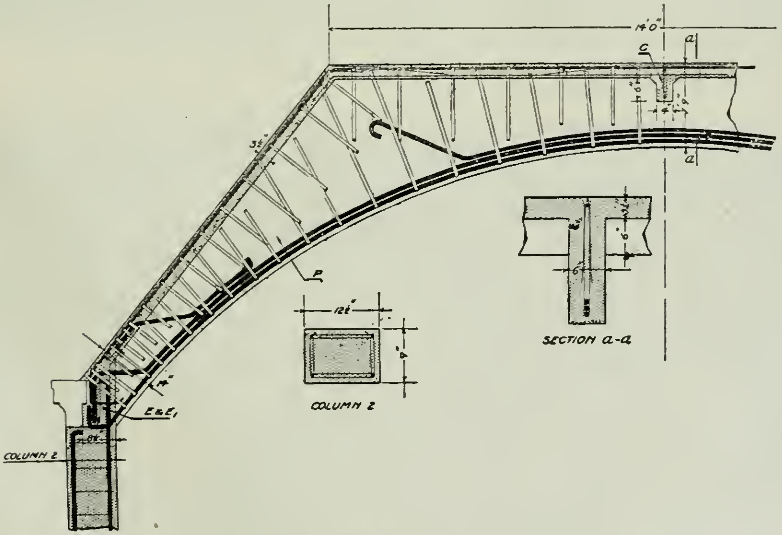


Fig. 1 Section of Main Roof over Refectory.
KING'S COLLEGE FOR WOMEN, CAMPDEN HILL, KENSINGTON.

The inception of the present building was the introduction in October, 1908, of special courses in Household and Social Science at King's College for Women, which at that time occupied premises in Kensington Square. The

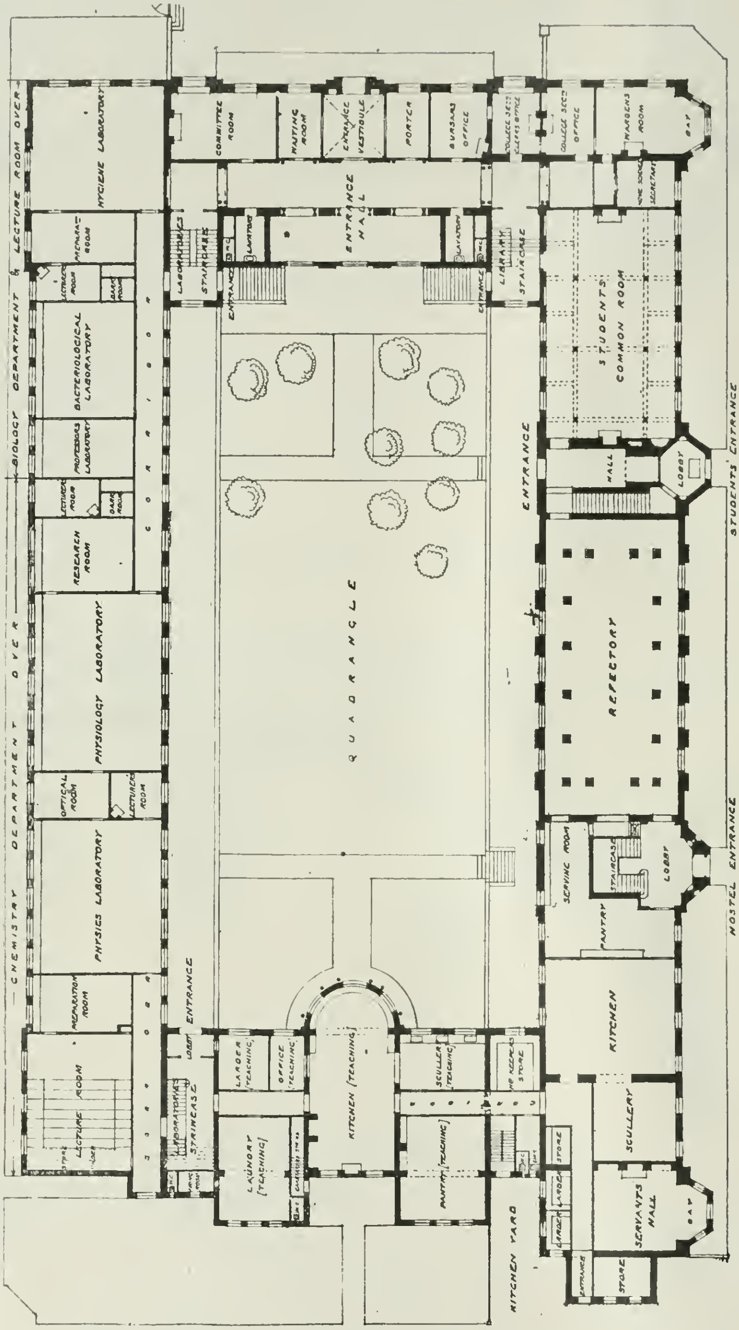


Fig. 2. Ground Floor Plan.
King's College for Women, Campden Hill, Kensington.

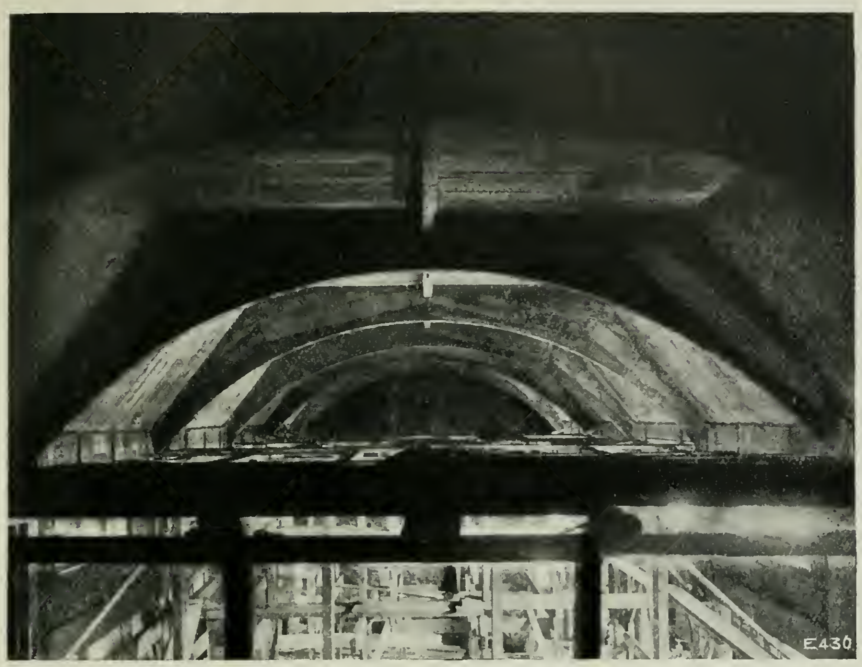


Fig. 3. Interior View, showing Roof Beams in Refectory Block.

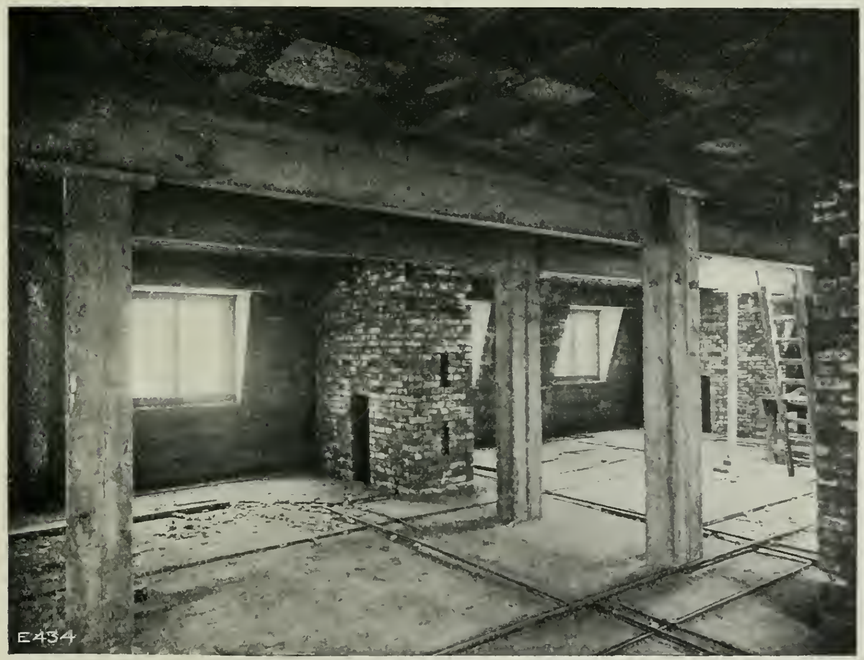
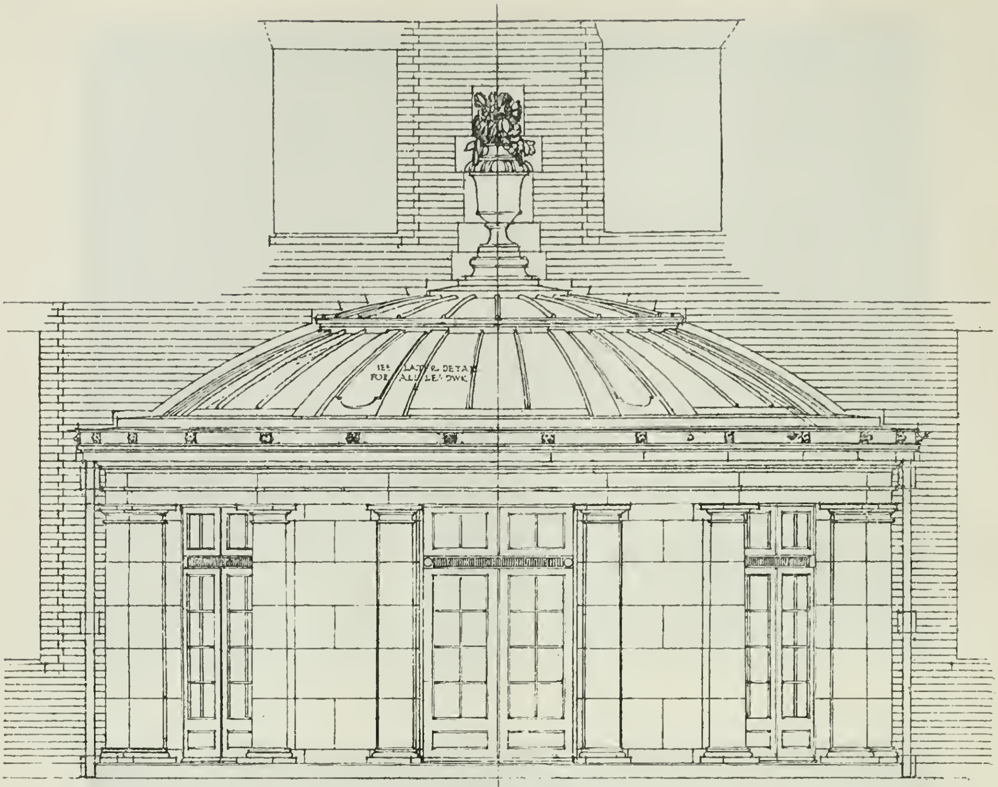
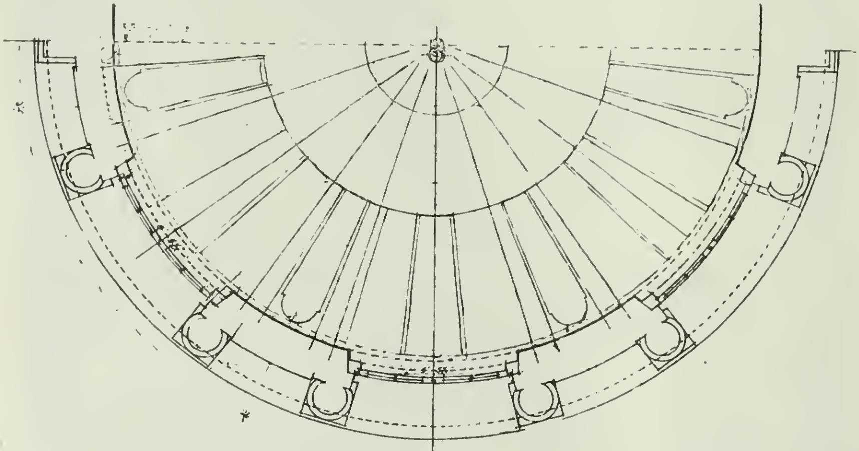


Fig. 4. Interior View.
KING'S COLLEGE FOR WOMEN, CAMPDEN HILL, KENSINGTON.



ELEVATION



PLAN

Fig. 5. Details of Bay to Teaching Kitchen.
King's College for Women, Campden Hill, Kensington.

object of these courses was to place the education of women in science and economics upon a wider and broader basis, and to fit them for the business and hygienic control of public institutions, factories and works, besides providing for the application of hygienic principles to the home alone.

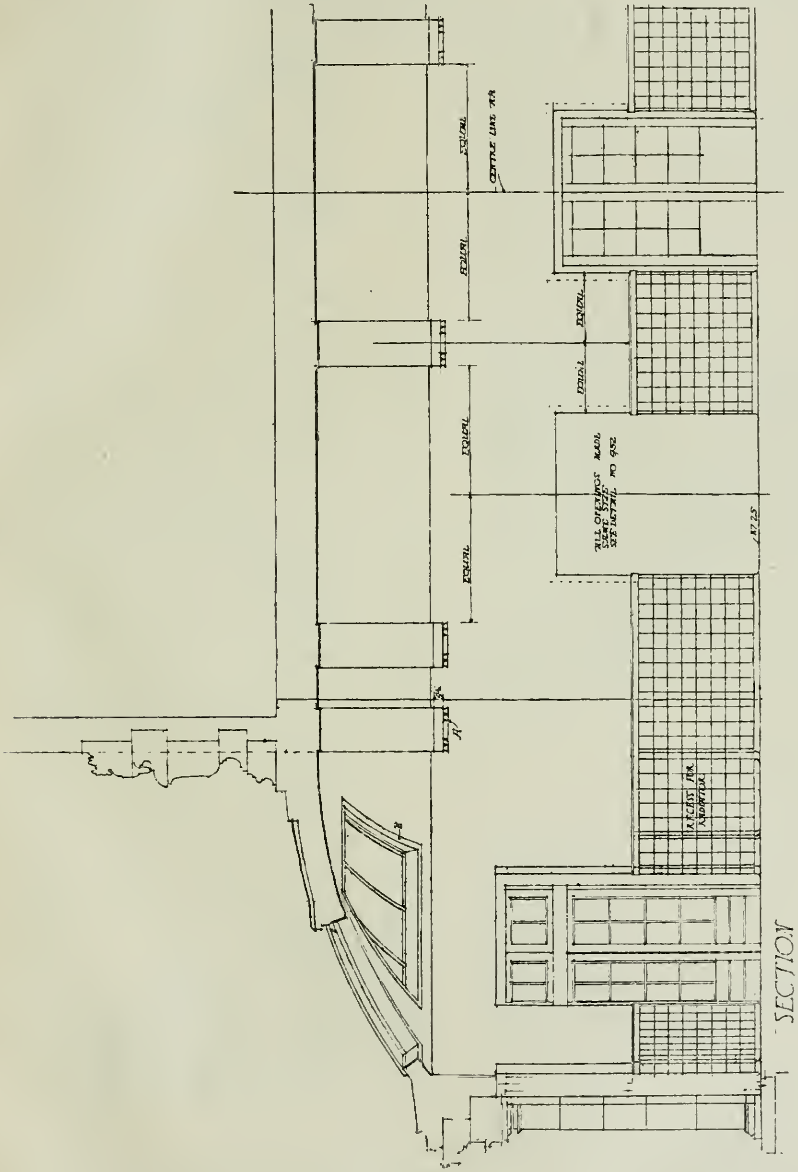


Fig. 6. Details of Bay to Teaching Kitchen.
King's College for Women, Campden Hill, Kensington.

This innovation was at first widely discussed, for the teaching of domestic science in a university seemed to many to be a sort of sacrilege; but the great interest taken in it by the Queen and many prominent educationists and workers in the realms of social reform had led to the scheme being a great success, and contributions to the amount of about £100,000 have already been received.

The Queen Mary Hostel, the Refectory, and the Anglesey Laboratories are now finished, and a portion of the buildings is being used.

Of these, the Hostel is the gift of Sir Richard Garton, the Laboratories of Lord Anglesey, and the Refectory has been built by Mrs. Wharrie, who has largely contributed towards endowing the College.

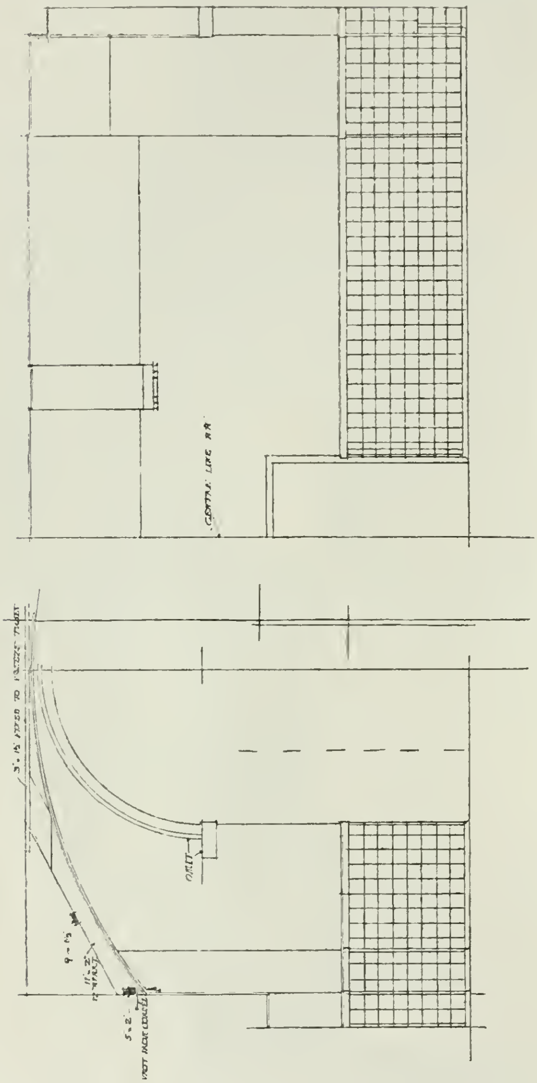


Fig. 7. Details of Bay to Teaching Kitchen.

King's College for Women, Campden Hill, Kensington.

The hostel serves not only as a home for the students, but allows for the principles of science studied to be applied in the same building in which the laboratories are situated. To each of the bed-sitting rooms, of which there are 57, a dressing-room is attached, and the remainder of the hostel block is occupied by the common rooms, isolation rooms, and the offices for the control of the College. Other noteworthy features of the building are the large teaching kitchen, with pantry and scullery attached, and the large teaching laundry. These buildings are equipped with appliances suited for all types of buildings, from large institutions down to small houses; and the kitchen laboratory is placed in close proximity to them.

Fig 1 shows the ground plan of the building, from which the arrangement of the whole scheme can be seen. In the construction of the work reinforced concrete, on the Mouchel-Hennebique system, has been widely used for floors, roofs, beams and supports; and the refectory is especially interesting, as

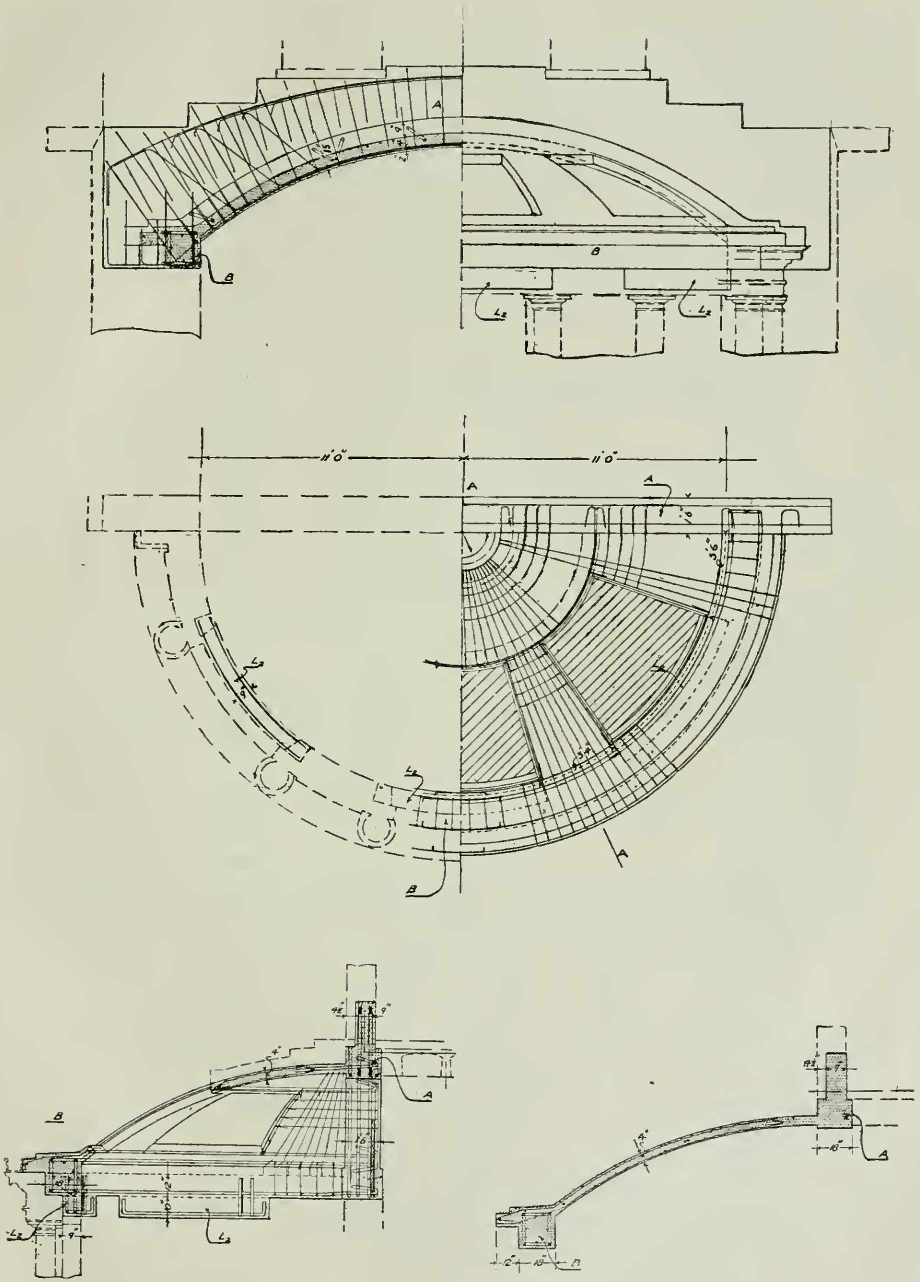


Fig. 8. Reinforced Concrete Details to Bay of Teaching Kitchen.
King's College for Women, Campden Hill, Kensington.

being, with the exception of external walls, entirely of this material. *Figs.* 9 and 10 show plan and sectional elevation of this room, which is 74 ft. long by 34 ft. wide, with a total height of 23 ft. 9 in. At one end is a gallery, carried on reinforced concrete columns, which range with the row of columns on either side carrying the clerestory wall and the main roof trusses. These trusses, as will be seen from *Figs.* 1 and 3, are 6 in. wide, and are designed so that the roof slab, which is 3½ in. thick, acts as a compression flange, and at the centre of the span is stiffened by a 6 in. by 4 in. longitudinal beam. The trusses are 14 in. deep at springing and 21 in. at the crown, and, as the underside follows a curve, a depth of 39 in. occurs midway between them.

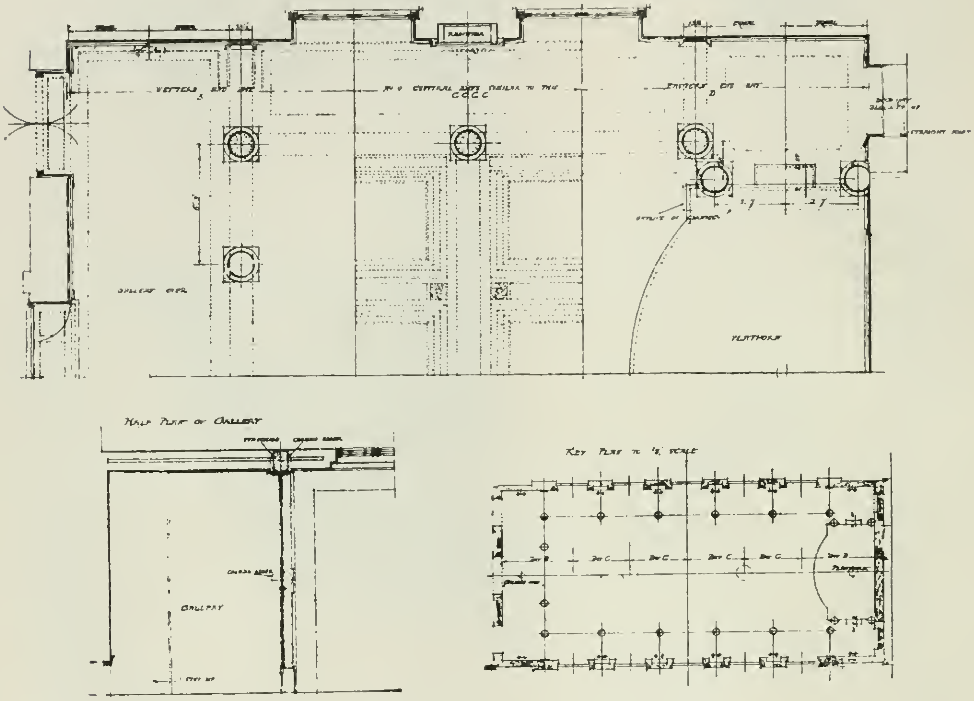


Fig. 9. Architectural Details of Finishing to Refectory.
King's College for Women, Campden Hill, Kensington.

Another unique feature is the large semi-circular bay to the teaching kitchen, details of which are shown in *Figs.* 5 and 6. It is 27 ft. wide, projects 13 ft. 6 in. into the quadrangle, and is finished with a reinforced concrete domed roof resting on a continuous beam connected to the concrete arch carrying the wall over the bay opening, and to allow for ample lighting to this kitchen three large skylight openings are formed in the semi-dome. *Fig.* 8 gives full details of its construction, and it will be noted that the dome is but 4 in. in thickness, and that the semi-circular beam has been designed to do its work and at the same time not to interfere with the proper bedding of the architectural stonework. The large concrete arch is

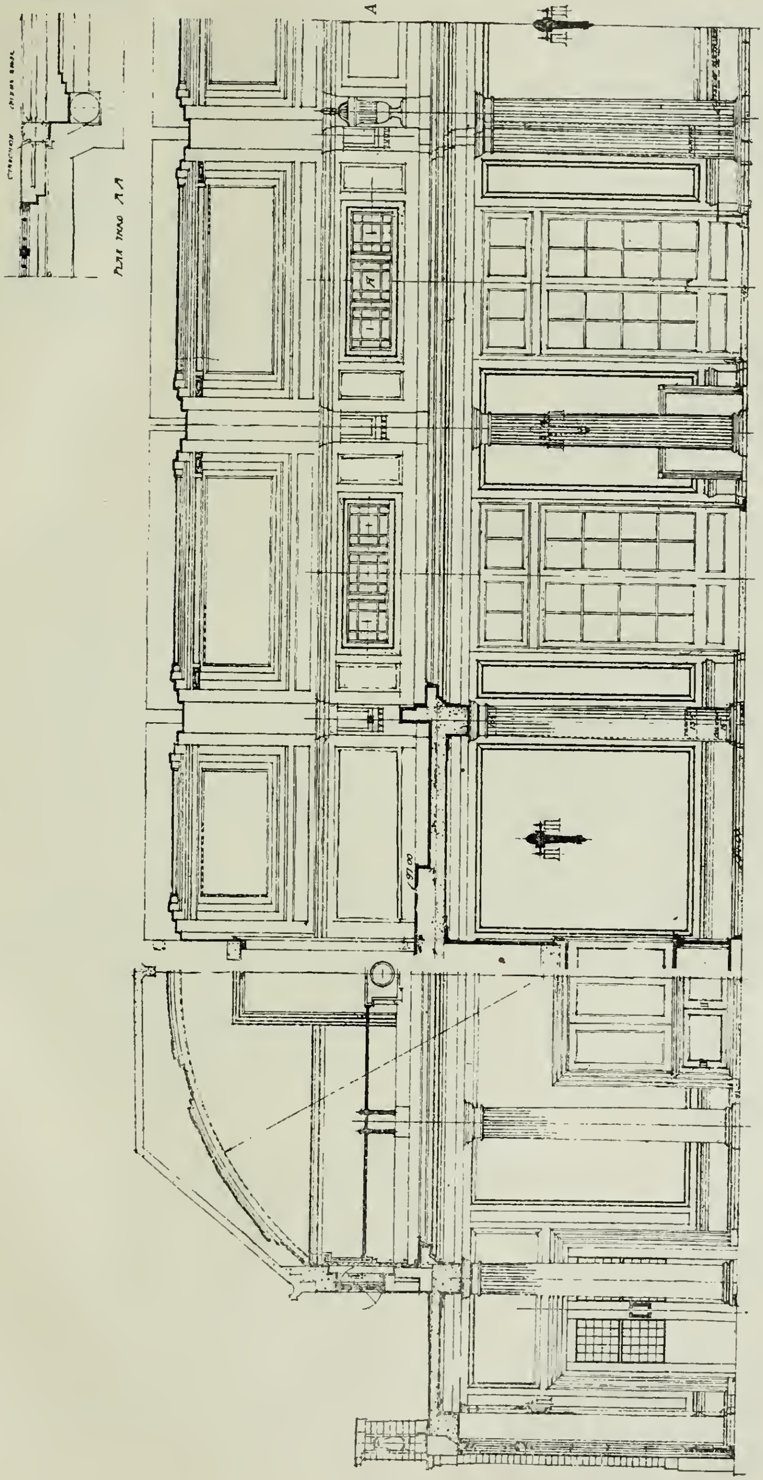


Fig. 10. Architectural Details of Finishing to Refectory.
King's College for Women, Campden Hill, Kensington.

also stepped on its upper surface to receive the brickwork in level courses, and is, moreover, designed of an inverted T section, in order that the continuity of the brick facing may be kept and the fine carved vase finish of the dome made perfectly structural. A beam showing on the exterior surface would have spoiled the whole effect of the quadrangle, and the effect aimed at by the architects destroyed.

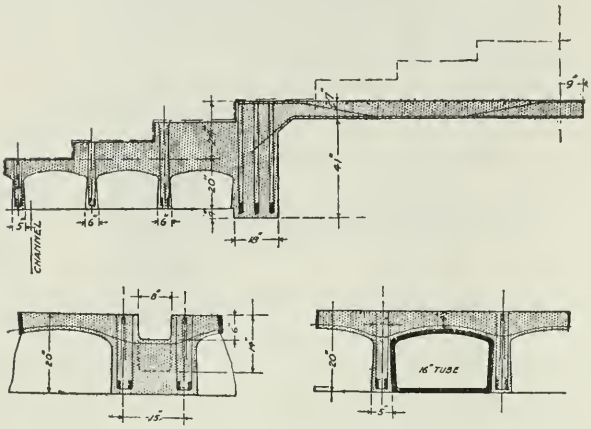


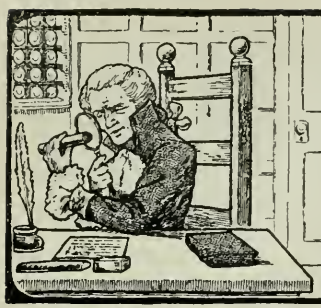
Fig. 11. Details of Floor Construction.
King's College for Women, Campden Hill, Kensington.

As previously mentioned, the floors and roofs are of reinforced construction, and *Fig.* 11 shows details of some of the special floor construction.

The building is completely heated by hot water, in addition to open fires in many rooms, and the care displayed in the details and working out of the whole scheme is worthy of study.

Externally, the whole structure is faced with fine red brickwork of pleasing surface, and with Portland stone dressings. The motif of the structure is late Georgian work, as exemplified at Hampton Court, and the building, which already expresses that indefinable spirit that hangs around the old Georgian work, will, when completed, be a noteworthy addition to the architecture of Campden Hill.

The architects for the work are Messrs. H. Percy Adams, F.R.I.B.A., and Charles Holden, A.R.I.B.A.; the contractors Messrs. Wallis and Sons, of Maidstone; and the whole of the reinforced concrete work has been designed by Messrs. L. G. Mouchel and Partners, Ltd., of 38, Victoria Street, Westminster.



RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

Continued from May issue, p. 233.—ED.

PART II.

MOMENT OF RESISTANCE OF DOUBLY REINFORCED BEAMS.

(*a*) *Statement of "equivalent concrete" theory and formulæ derived from it.*

The treatment of compressive reinforcement in doubly reinforced beams, to which the writer will refer for convenience as the "equivalent concrete" treatment, is fully explained in "Reinforced Concrete Design," pages 40-44, and the following may be given as a short statement.

Considering a fibre in compression, it follows that if there is no slipping between the bar and the concrete the strain in the bar and in the concrete immediately surrounding it must be the same, and hence the stresses are proportional to the moduli of the materials. In other words, taking the usual value for E_c and E_s, the stress in the steel is fifteen times that of the concrete at that distance from the neutral axis, and the steel bar has exactly the same effect as if it were replaced by fifteen times its area of concrete.

The reader is referred to "Reinforced Concrete Design," pages 41-43, for a method by which doubly reinforced beams may conveniently be calculated and designed in a manner consistent with this theory, and as it would take up considerable space the treatment will not be given here.

This method of treating compression reinforcement has never had much serious opposition when the percentage of steel has been reasonably low—say up to 1·0 per cent.—and the only criticism of any note has centred on the correctness of $m=15$, and suggestions that the stress curve in the concrete might be taken as parabolic instead of linear.

The difficulty occurs when the percentage is large. This may be seen from the following considerations.

Consider a simple rectangular beam of reinforced concrete in which the steel in tension and the concrete in compression are stressed to the usual limiting safe stresses of

$$t = 16{,}000 \text{ lbs./in.}^2$$
$$c = 600 \text{ lbs./in.}^2$$

It follows that if we make the usual assumptions that—

(1) the concrete will resist no tension,

(2) the ratio $\dfrac{E_s}{E_c}$ may be taken as constant and equal to 15,

(3) plane sections remain plane after bending,

that with these stresses the depth of the neutral axis will be

$$n = \cdot 36d,$$

and the percentage of steel reinforcement in tension will be

$$p = \cdot 675 \text{ per cent.} \quad \text{(See "R.C.D.," page 31.)}$$

The moment of resistance of this singly reinforced beam is expressed by the formula—

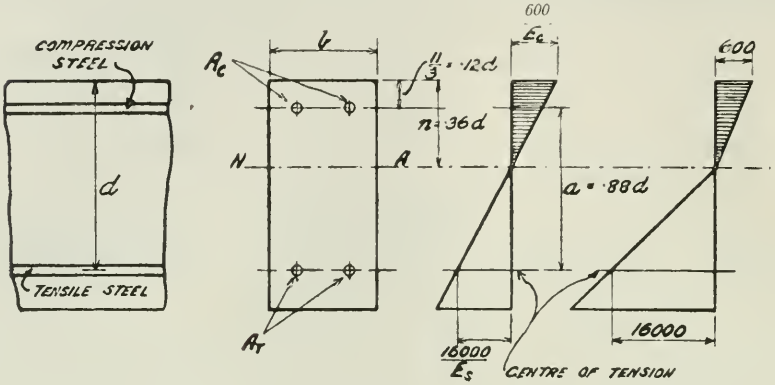
$$R = 95bd^2$$

If it is now required to increase the moment of resistance of the beam without increasing its dimensions, we may add more steel to the tension flange and simultaneously provide compression reinforcement.

We will in the present analysis place this latter at a distance of $\cdot 12d$ from the top of the beam. This greatly simplifies analysis, in that it coincides with the centre of compression of the concrete, and so keeps the arm of the couple constant, whereas if it were placed elsewhere this arm would vary with the amount of compression reinforcement.

It may be remarked that this position also agrees well with most practical examples.

The conditions are now as in *Fig.* 8.



Strain Diagram. Stress Diagram.

FIG. 8. TO ILLUSTRATE STEEL IN COMPRESSION.

It will be noticed from the foregoing that as the compression steel is on a fibre at $2/3\ n$ from the neutral axis, the stress on the concrete here is $2/3 \cdot c = 400$ lbs./in.²

Hence the stress at this point is—

$$\frac{E_s}{E_c} \cdot 400 = 15 \times 400 = 6{,}000 \text{ lbs./in.}^2$$

As the effect of adding one square inch of compression steel is to deduct one square inch of concrete in compression, the additional force in the compression boom due to one square inch of steel is

$$400\ (15 - 1) = 5{,}600 \text{ lbs./in.}^2$$

Remembering that the stress in the steel on the tension flange is 16,000 lbs./in.², and that the total tension must still remain equal to the total compression, it follows that for every square inch of steel we add on the tension flange we have to add

$$\frac{16{,}000}{5{,}600} = 2 \cdot 86 \text{ sq. in.}$$

of steel on the compression side, if we are still to keep within the safe limiting stress of 600 in compression.

Consider now the effect of this, which is clearly shown by the following table:

Tension Steel.	Compression Steel.
·675%	None
·675% + ·1 = ·775	·286
·675% + ·2 = ·875	·572
·675% + ·3 = ·975	·858
·675% + ·4 = 1·075	1·144
·675% + ·5 = 1·175	1·430

and so on.

It will be seen that when the percentage is increased much above 1 per cent. more compression than tensile steel has to be provided, although the concrete assists in resisting compression, but not in resisting tension.

This at first sight paradoxical result is, of course, due to the fact that the steel is fully stressed in tension, but cannot be fully stressed in compression without overstressing the concrete.

Up to the limit of about 1 per cent. there is no question but that the method of design based on the above is substantially correct.

(*b*) *Statement of "equal steel top and bottom" theory.*

When, however, the percentage has to be kept well above 1 per cent., and the steel in compression with this method of design becomes greater in area than that in tension, a more modern school of design has suggested that it becomes more economical to neglect the resistance of the concrete in compression, and stress the compression steel to 16,000 lbs./in.^{2}

For example, consider the case when it becomes necessary to have 2 per cent. of steel on the tension side stressed to 16,000 lbs./in.^{2}, and it is required to strengthen the compression flange accordingly.

Under method *a* the compression flange consists of concrete stressed to a maximum stress at the extreme fibre of 600 lbs./in.^{2}, and 3·78 per cent. of compression steel stressed to 6,000 lbs./in.^{2}

Under method *b* no reliance is placed on the concrete in compression, and the whole compression is taken by 2 per cent. of steel stressed to 16,000 lbs./in.^{2}

A comparative statement of the two methods of design may be found in the following interesting evolution of the L.C.C. (General Powers) Act, 1909.

In the draft regulations, dated 23/7/14, are the following clauses:—

"COMPRESSIVE REINFORCEMENT.

"61. Where compressive reinforcement is provided in beams, the cross sectional area of the concrete may be assumed to be increased at the same distance from the neutral axis by an area $(m-1)$ times the cross sectional area of the compressive reinforcement.

"62. The stress in the compressive reinforcement shall not be greater than m times the stress in the concrete at the same distance from the neutral axis."

This is, of course, the method *a* of the text.

Later, in 1914, when these draft regulations came before the Councils of the Concrete Institute and of the Royal Institute of British Architects, it was proposed to substitute for the above a fresh Clause 62, as follows:—

"62. In cases where the compressive resistance of the concrete is not taken into account, the stress in the compressive reinforcement may be taken at 16,000 lbs. per sq. in., on condition that

"(*a*) sufficient steel is provided to take up the whole of the compression,

"(*b*) the compressive reinforcement is anchored laterally and vertically by anchors not further apart (centre to centre) than 6 in. and not further apart than eight times the diameter of anchored bar,

"(*c*) the anchor shall be passed round or hooked over both the compressive and tensile reinforcement."

This is, of course, the method *b* of the text.

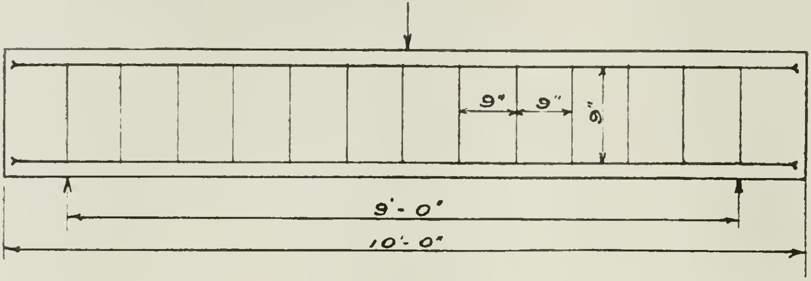
The economy of the second method is unquestionable, but its justification is, in the opinion of the writer, distinctly doubtful. It appeared to the writer that the concrete, if overstressed and fractured, would not remain so much self-effacing material, allowing the steel to behave quite independently as is obviously assumed, but by its fracture would cause a great tendency to buckling of this reinforcement, besides destroying the concrete web through which these stresses are transmitted. For this reason the writer has argued that the method of design *b* involves a reduction in the factor of safety, while in his opinion method *a* gives a factor of 4 with usual percentages, rising slightly with extreme values, but not so much so as to require this to be allowed for in practice. The following beams were made to test this:—

(c) *Description of experiments.*

Beams Nos. 9-16 were made as shown in *Fig.* 9. They were 12 in. deep, 8 in. wide, 10 ft. long, and tested with a central point load on a 9-ft. span.

They were reinforced with two bars top and bottom, gradually increasing in diameter from beam No. 9 (2-½ in. bars) to beam No. 16 (2-1⅜ in. bars).

The bars were provided with a fishtail each end. They were connected with links spaced at 9 in. centres, the links having four effective strands every 9 in., and consisting of ¼ in. mild steel for beams 9-12, ⅜ in. for beams 13-15, and ½ in. for beam 16.



Beam No	Reinforcement	Links	
		Size	Inside diam of links
9	2 - ½" ∅ X	¼"	9½"
10	2 - ⅝" ∅ "	do.	9⅝"
11	2 - ¾" ∅ "	do	9¾"
12	2 - ⅞" ∅ "	do	9⅞"
13	2 - 1" ∅ "	⅜"	10"
14	2 - 1⅛" ∅ "	do	10⅛"
15	2 - 1¼" ∅ "	do	10¼"
16	2 - 1⅜" ∅ "	½"	10⅜"

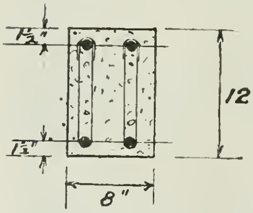


FIG. 9. BEAMS 9—16.
(Series 1912-13.)

X Top and bottom.

The object of the links was to prevent the compression bars buckling and to increase the resistance of the beams to shear and adhesion, so that failure should take place in the one form under test—namely, by bending.

The materials of which the beams were made were exactly the same as for beams 1 to 8 (already described), and the beams were made and tested at the age of four months at the same times as before.

All the beams of the series failed slowly with plenty of warning; beams 14 to 16 a little less so than the rest.

Figs. 10 to 13 show the beams after failure.

The nature of the failure would seem to indicate that beams 9-11 failed in tension, while beams 12-16 developed small tension cracks early in the test, as usual, and the opening of these coincided with failure of the top concrete in compression, making it difficult to say to which cause failure was due. It is, however, quite simple to see from analysis (see later).

It is obvious from the form of the cracks that failure did not occur by slipping of either tension or compression bars or by shear.

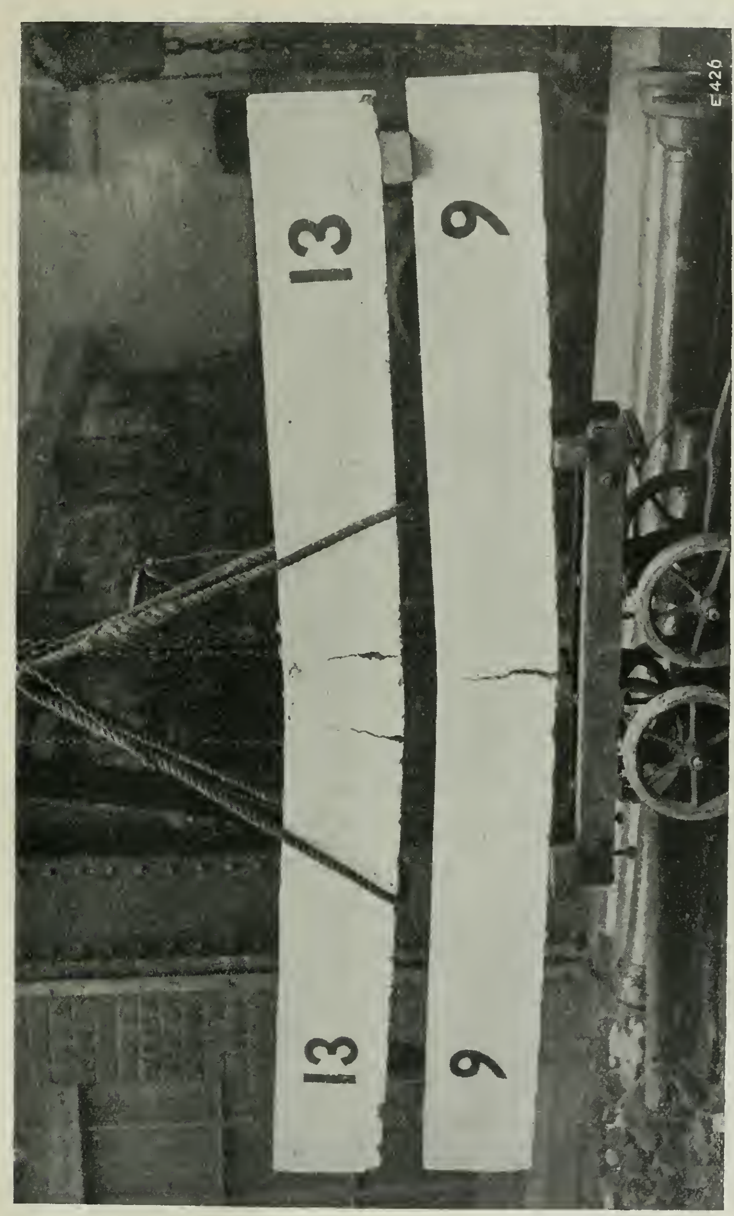


FIG. 10.

(*d*) *Calculation of safe moments of resistance.*

(1) By method (*a*). The calculations are made as explained in "Reinforced Concrete Design," pages 40 to 43.

The method consists in assuming a value for the depth of the neutral axis; this may be done by an experienced person with some accuracy, remembering that where compression reinforcement is provided the neutral axis will be somewhat higher than in a singly reinforced beam having the same percentage on the tension side.

The value of the compressive reinforcement relative to the concrete may

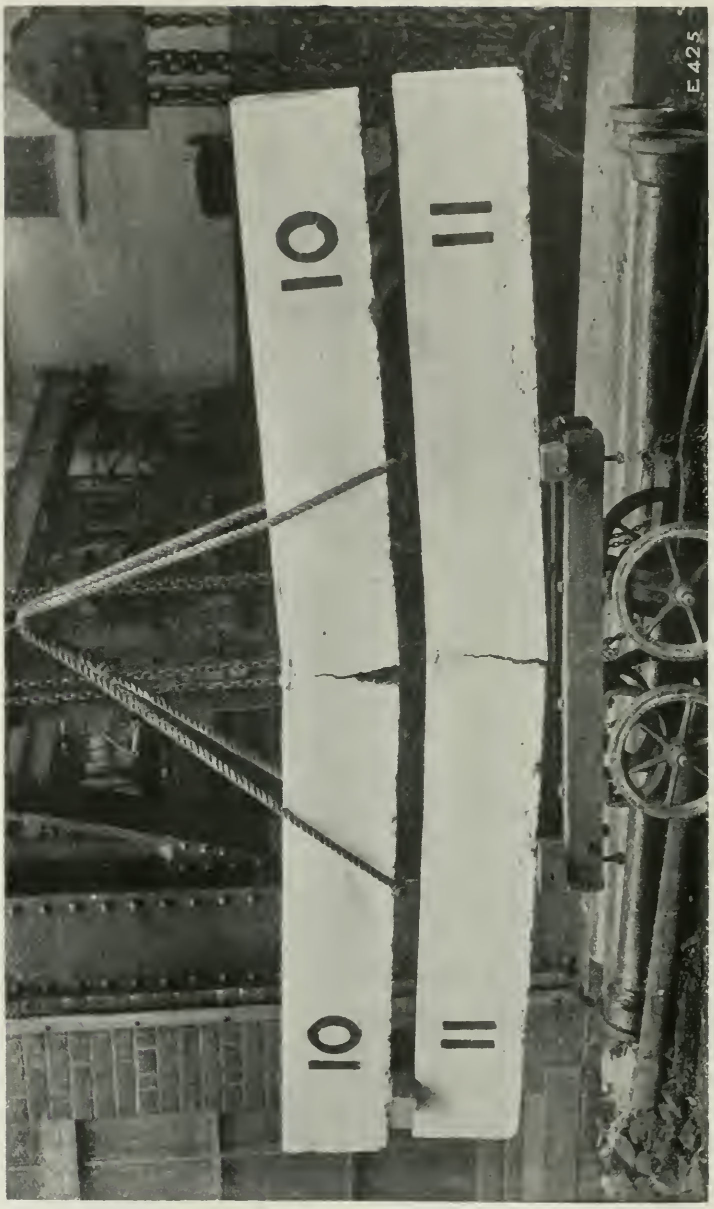


FIG. 11.

then be calculated, and the beam replaced by a proportionately broader one without compression steel.

This equivalent beam may then be analysed by the usual formulæ, as for beams 1 to 8, or by the curves given in "R.C.D.," *Figs.* 10-16.

Beam 9. $p = \frac{2 \times \cdot196}{8 \times 10\frac{1}{2}} = 467$

n (neglecting comp. reinforcement) would be 3·28 in. (see Table I.).

Take $n = 3\cdot0$ in.

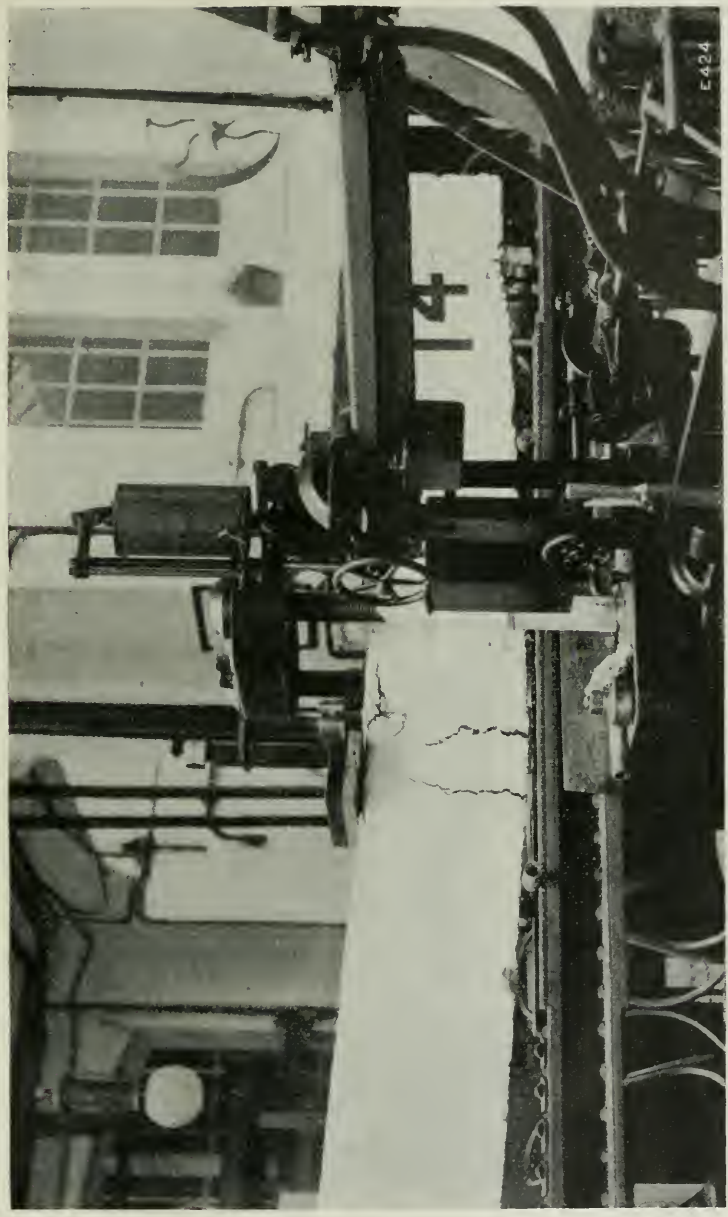


FIG. 12.

Then compression in concrete $= \frac{1}{2}c \times 8 \text{ in.} \times 3 \text{ in.} = 12c$.

Remembering that the additional compression from the compression bars is:—

$$A_c \times 14c \times \frac{n - d_c}{n}$$

when $n - d_c =$ distance of bars from the neutral axis we have

$$\text{Additional compression from steel bars} = \cdot 392 \times 14c \times \frac{1\cdot 5}{3\cdot 0} = 2\cdot 75c$$

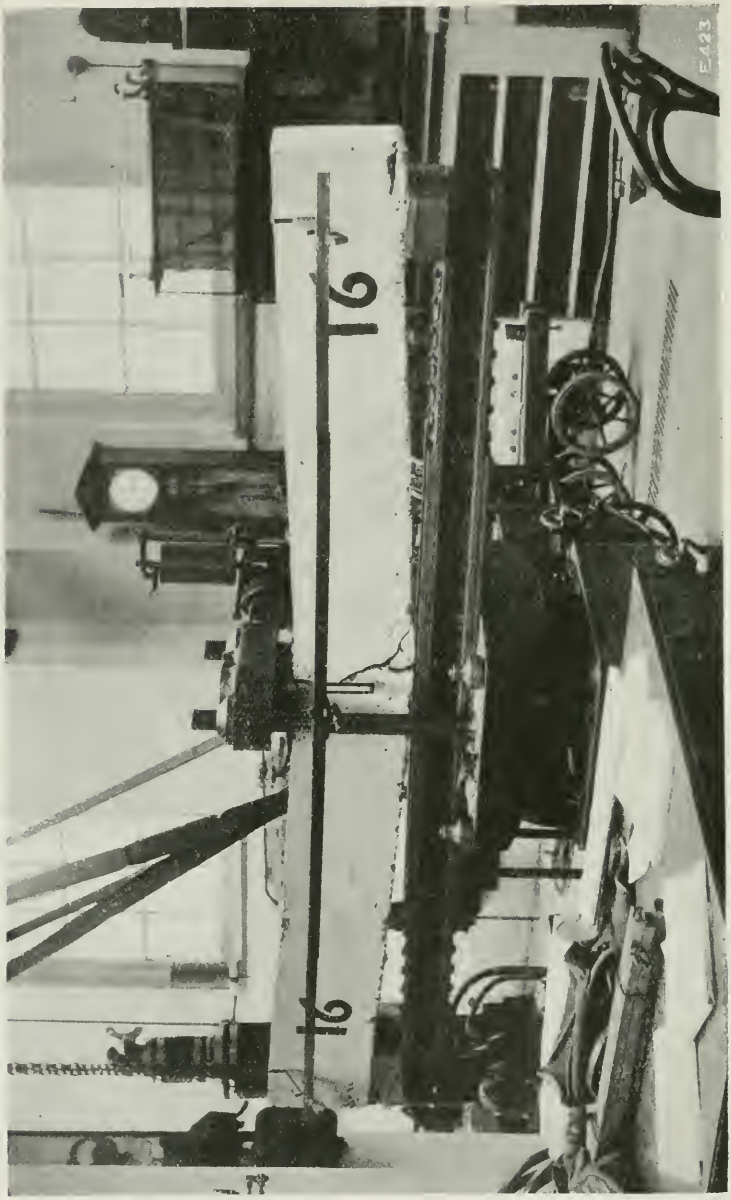


FIG. 13.

Hence the beam is equivalent to a beam without compression reinforcement having a width of

$$8 \times \frac{12+2\cdot75}{12} = 9\cdot8 \text{ in.}$$

For this equivalent beam $p = \frac{2 \times \cdot196}{9\cdot8 \times 10\frac{1}{2}} = \cdot38$

$$n = \cdot275 \times 10\tfrac{1}{2} \text{ (R.C.D., } \textit{Fig. } 10)$$
$$= 2\cdot9 \text{ in.}$$

$$t = \frac{n \times 100}{2p} \text{ (R.C.D., page 29)}$$

$$= \frac{26}{{\cdot}55} = 47{\cdot}2$$

Hence if $t = 16{,}000$

$$c = \frac{16{,}000}{47{\cdot}2} = 395 \text{ lbs./in.}^2$$

$$R = 16{,}000 \times 2 \times {\cdot}196 \times \left(10{\cdot}5 - \frac{2{\cdot}9}{3}\right)$$

$$= 60{,}000 \text{ in.-lbs.}$$

Safe central load $W = \frac{4R}{2} = 2{,}220$ lbs.

Stress in compression steel $c_s = 15 \times 395 \times \frac{1{\cdot}4}{2{\cdot}9} = 2.860$

Beam 10. $b = {\cdot}73$

$n = 3{\cdot}88$

Take $n = 3{\cdot}5$

C in concrete $\frac{c}{2} \times 8 \times 3{\cdot}5 = 14c$

C in steel ${\cdot}6 \times 14c \times \frac{2}{3{\cdot}5} = 4{\cdot}8c$

Width of equivalent beam $8 \times \frac{18{\cdot}8}{14} = 10{\cdot}7$ in.

$$p^1 = \frac{{\cdot}6}{10{\cdot}7 \times 10{\cdot}5} = {\cdot}533$$

$n = {\cdot}33 \times 10{\cdot}5 = 3{\cdot}47$ in. (R.C.D., *Fig.* 10)

$t_1 - 31$ (R.C.D., *Fig.* 12)

Taking $t = 16{,}000$ $c = \frac{16{,}000}{31} = 515$ lbs./in.²

$R = 76 \times 10{\cdot}7 \times 10{\cdot}5^2$ (R.C.D., *Fig.* 16

$= 90{,}000$ in.-lbs.

$$W = \frac{90{,}000}{27} = 3{,}330 \text{ lbs.}$$

$$C_s = 515 \times 15 \times \frac{1{\cdot}97}{3{\cdot}47} = 4{\cdot}390 \text{ lbs. in.}^2$$

Beam 11. $p = 1{\cdot}05$

$n = 4{\cdot}42$

Take $n = 4{\cdot}$

C in concrete $= \frac{c}{2}.\ 8{\cdot}4 = 16c$

C in steel $= {\cdot}88 \times 14c \times \frac{2{\cdot}5}{4} = 7{\cdot}7c$

Width of equivalent beam $\frac{8 \times 23{\cdot}7}{16} = 11{\cdot}8$ in.

$$p^1 = \frac{{\cdot}88}{11{\cdot}8 \times 10{\cdot}5} = {\cdot}71$$

$n = {\cdot}367 \times 10{\cdot}5 = 3{\cdot}85$ in. (R.C.D., *Fig.* 10)

$t_1 = 26$ (R.C.D., *Fig.* 12)

Taking $c = 600$, $t = 600 \times 26 = 15{,}600$ lbs./in.²

$R = 96 \times 11{\cdot}8 \times 10{\cdot}5^2$ (R.C.D., *Fig.* 16)

$= 125{,}000$ in./lbs.

$$W = \frac{R}{27} = 4{,}620$$

$$C_s = 15 \times 600 \times \frac{2{\cdot}35}{3{\cdot}86} = 5{,}500 \text{ lbs./in.}^2$$

Beam 12. $p = 1{\cdot}43$

$n = 4{\cdot}96$

Take $n = 4{\cdot}2$

$$C \text{ in concrete} = \frac{c}{2} \times 8 \times 4{\cdot}2 = 16{\cdot}8c$$

$$C \text{ in steel} = 1{\cdot}2 \times 14c \times \frac{2{\cdot}7}{4{\cdot}2} = 10{\cdot}8c$$

$$\text{Width of equivalent beam} = \frac{8 \times 27{\cdot}6}{16{\cdot}8} = 13{\cdot}1 \text{ in.}$$

$$p^1 = \frac{1{\cdot}2}{13{\cdot}1 \times 10{\cdot}5} = {\cdot}875$$

$n = {\cdot}397 \times 10{\cdot}5 = 4{\cdot}16$ (R.C.D., *Fig.* 10)

$t_1 = 22{\cdot}8$ (R.C.D., *Fig.* 12)

Taking $c = 600$, $t = 600 \times 22{\cdot}8 = 13{,}650$ lbs./in.^{2}

$R = 103 \times 13{\cdot}1 \times 10{\cdot}5^2$ (R.C.D., *Fig.* 16)

$= 148{,}500$ in.-lbs.

$W = 5{,}500$ lbs.

$$C_s = 15 \times 600 \times \frac{2{\cdot}66}{4{\cdot}16} = 5{,}750 \text{ lbs. in.}^2$$

Beam 13. $p = 1{\cdot}87$

$n = 5{\cdot}46$ in.

Take $n = 4{\cdot}4$

$$C \text{ in concrete} = \frac{c}{2} \times 8 \times 4{\cdot}4 = 17{\cdot}6c$$

$$C \text{ in steel} = 1{\cdot}56 \times 14c \times \frac{2{\cdot}9}{4{\cdot}4} = 14{\cdot}4c$$

$$\text{Width of equivalent beam } \frac{8 \times 32}{17{\cdot}6} = 14{\cdot}5 \text{ in.}$$

$$p^1 = \frac{1{\cdot}56}{14{\cdot}5 \times 10{\cdot}5} = 1{\cdot}03$$

$n = {\cdot}418 \times 10{\cdot}5 = 4{\cdot}4$ in. (R.C.D., *Fig.* 10)

$t_1 = 20{\cdot}5$ (R.C.D., *Fig.* 12)

$c = 600$, $t = 20{\cdot}5 \times 600 = 12{,}300$ lbs. in.^{2}

$R = 108 \times 14{\cdot}5 \times 10{\cdot}5^2$ (R.C.D., *Fig.* 16)

$= 173{,}000$ in.-lbs.

$W = 6{,}400$ lbs.

$$C_s = 600 \times 15 \times \frac{2{\cdot}9}{4{\cdot}4} = 5{,}940 \text{ lbs. in.}^2$$

Beam 14. Take $n = 4{\cdot}6$

$$C \text{ in concrete} = \frac{c}{2} \times 8 \times 4{\cdot}6 = 18{\cdot}4c$$

$$C \text{ in steel} = 2{\cdot}0 \times 14c \times \frac{3{\cdot}1}{4{\cdot}6} = 18{\cdot}8c$$

$$\text{Width of equivalent beam} = 8 \times \frac{37{\cdot}2}{18{\cdot}4} = 16{\cdot}15$$

$$p^1 = \frac{2}{16{\cdot}15 \times 10{\cdot}5} = 1{\cdot}18$$

$n = {\cdot}44 \times 10{\cdot}5 = 4{\cdot}61$ in. (R.C.D., *Fig.* 10)

$t_1 = 18{\cdot}9$ (R.C.D., *Fig.* 12)

$c = 600$, $t = 18{\cdot}9 \times 600 = 11{,}340$ lbs. in.^{2}

$R = 112{\cdot}5 \times 16{\cdot}15 \times 10\tfrac{1}{2}^2$ (R.C.D., *Fig.* 16)

$= 200{,}000$ in.-lbs.

$W = 7{,}400$ lbs.

$$c_s = 600 \times 15 \times \frac{3{\cdot}11}{4{\cdot}61} = 6{,}080 \text{ lbs. in.}^2$$

Beam 15. Take $n=4{\cdot}8$

$$C \text{ in concrete}=\frac{c}{2}\times8\times4{\cdot}8=19{\cdot}2c$$

$$C \text{ in steel}=2{\cdot}44\times14c\times\frac{3{\cdot}3}{4{\cdot}8}=23{\cdot}5c$$

$$\text{Width of equivalent beam}=8\times\frac{42{\cdot}7}{19{\cdot}2}=17{\cdot}8 \text{ in.}$$

$$p^1=\frac{2{\cdot}44}{17{\cdot}8\times10{\cdot}5}=1{\cdot}305$$

$n={\cdot}457\times10\tfrac{1}{2}\times4{\cdot}79$ in. (R.C.D., *Fig.* 10)

$t_1=17{\cdot}9$ (R.C.D., *Fig.* 12)

$c=600,\ t=17{\cdot}9\times600=10{\cdot}740$ lbs./in.^{2}

$R=116\times17{\cdot}8\times10{\cdot}5^2$ (R.C.D., *Fig.* 16)

$=227{,}000$ in.-lbs.

$W=8{,}400$ lbs.

$$c_s=600\times\frac{3{\cdot}29}{4{\cdot}79}\times15=6{,}190 \text{ lbs./in.}^2$$

Beam 16. Take $n=5{\cdot}0$

$$C \text{ in concrete}=\frac{c}{2}\times8\times5=20c$$

$$C \text{ in steel}=2{\cdot}96\times14c\times\frac{3{\cdot}5}{5{\cdot}0}=29c$$

$$\text{Width of equivalent beam}=8\times\frac{49}{20}=19{\cdot}6 \text{ in.}$$

$$p^1=\frac{2{\cdot}96}{19{\cdot}6\times10{\cdot}5}=1{\cdot}44$$

$n={\cdot}474\times10\tfrac{1}{2}=4{\cdot}98$ in. (R.C.D., *Fig.* 10)

$t_1=16{\cdot}7$ (R.C.D., *Fig.* 12)

$c=600.\ t=16{\cdot}7\times600=10{,}020$ lbs./in.^{2}

$R=120\times19{\cdot}6\times10{\cdot}5^2$ (R.C.D., *Fig.* 16)

$=260{,}000$ in.-lbs.

$W=9{,}600$ lbs.

$$c_s=600\times\frac{3{\cdot}48}{4{\cdot}98}\times15=6{,}300 \text{ lbs./in.}^2$$

(2) By method (*b*). Calculation by this method is, of course, extremely simple. consisting simply in calculating:

Area of steel × stress × radius arm.

Thus for beam 9—

$$R={\cdot}392\times16{,}000\times9=56{,}500 \text{ in.-lbs.}$$

$$W=\frac{4R}{l}=\frac{R}{27}=2{,}090 \text{ lbs.}$$

(*e*) *Deductions.*

The results of the calculations by method (*a*) are given in Table IV. and the results of experiments in Table V.

TABLE IV.

TABULATION OF CALCULATIONS BY METHOD (A).

Beam No.	Reinforcement.	A Area steel.	p $\frac{A}{bd}$	n Depth of N.A.	R Safe Res. Mom.	W Safe Load.	c Stress concrete.	t Stress tension steel.	c_s Stress comp. steel.
		in.^{2}		in.	in.-lbs.	lbs.	lbs./in.^{2}	lbs./in.^{2}	lbs./in.^{2}
9	2 - ½″ dia.	·392	·467	2·9	60,000	2,220	395	16,000	2,860
10	2 - ⅝″ ,,	·60	·73	3·47	90,000	3,330	515	16,000	4,390
11	2 - ¾″ ,,	·88	1·05	3·85	125,000	4,620	600	15,600	5,500
12	2 - ⅞″ ,,	1·20	1·43	4·16	148,000	5,500	600	13,650	5,750
13	2 - 1″ ,,	1·56	1·87	4·40	173,000	6,400	600	12,300	5,940
14	2 - 1⅛″ ,,	2·00	2·38	4·61	200,000	7,400	600	11,340	6,080
15	2 - 1¼″ ,,	2·44	2·90	4·79	227,000	8,400	600	10,740	6,190
16	2 - 1⅜″ ,,	2·96	3·56	4·98	260,000	9,600	600	10,020	6,300

TABLE V.

Comparison of Experimental Results with Calculations by Method (a).

Beam No.	Safe W Calculated.	Ultimate W Experiment.*	Factor of Safety.
9	2 220	10,600	4·8
10	3,330	12,950	3·9
11	4,620	18,180	4·0
12	5,500	20,450	3·7
13	6,400	31,450	4.9
14	7,400	33,680	4.5
15	8,400	41,080	4.9
16	9,600	38,950	4.1

* The loads in this column have been increased by 450 lb. to allow for ½ wt. of beam.

It may be said as a general deduction that, having regard to the great variation in our variable p ·467 to 3·56, to the unavoidable differences in concrete, and to the errors of experiments, that the factors are sensibly constant and are of the order of the value 4, which was taken in the determination of the safe stresses in the component materials.

It is interesting to note that the slight variations in the factor noted in the singly reinforced beams are noticeable here also.

1. The beams with the lowest factor—Nos. 10-12—are those where both materials are highly stressed simultaneously.

2. Under-reinforced beams, such as No. 9, show a larger factor, because of the effect of the assistance of the concrete in tension (see p. 297 and *Fig.* 5).

3. Over-reinforced beams, such as Nos. 13 upwards, show a larger factor because of the effect of the reduction of the modulus of concrete at ultimate conditions (see p. 297 and *Fig.* 7).

We will now—in Table VI.—tabulate the safe loads as calculated by method (b), and show how they compare with experimental results.

TABLE VI.

Calculation of Beams by Method (b) and Comparison with Experiments.

Beam Number.	p.	Resistance Moment.	Safe Load.	Ultimate Load.	Factory of Safety.
		in.-lbs.	lbs.	lbs.	
9	0·467	56,500	2,090	10,600	5·1
10	0·73	86,500	3,210	12,950	4·0
11	1·05	127,000	4,700	18,180	3·9
12	1·43	173,000	6,400	20,450	3·2
13	1·87	225,000	8,320	31,450	3·8
14	2·38	288,000	10,650	33,680	3·2
15	2·90	351,000	13,000	41,080	3·2
16	3·56	426,000	15,800	38,950	2·5

It will be seen that the factor falls off gradually from 5·1 with $p = ·467$ to 2·5 with $p = 3·56$, showing clearly that the steel in compression will not resist a stress of 16,000 lbs. in.^{2} with a factor even approaching 4. It is obvious, for this reason alone, that the theory cannot pretend to approximate to the actual conditions existing in the beam, and the writer would conclude that there are dangers in its use.

As a matter of fact, it will be seen that the factor is only good up to about $p = 1$; that is, under conditions where the limiting condition is first reached on the tension side and not on the compression side at all, and that as soon as the compression side becomes the limiting factor, and calculations are made by this formula, the factor of safety is reduced more and more with increasing values of p.

For these reasons the writer concludes that in spite of its simplicity, which will tempt some designers, it is a bad method of design, and cannot compare with method (a) either in safety or in its approximation to the actual conditions existing in the beam.

It is interesting to notice the conditions as regards shear and adhesion. Considering beam 15, both because it sustained the greatest load and had smaller links than No. 16, we have—

Max. shear across section = 20,540 lbs.

Calculating the safe shear by the usual formulæ (see Part III.) we have—

$$\text{Shear by concrete} = 60 \times 8 \text{ in.} \times 8{\cdot}9 \text{ in.} = 4{,}280 \text{ lbs.}$$
$$\text{Shear by stirrups} = 4 \times {\cdot}11 \times 16{,}000 = 7{,}040 \;\;,,$$
$$11{,}320 \text{ lbs.}$$

This gives a factor of 1·8 as against 4·9 against bending, showing conclusively that failure did not occur by shear, which is confirmed by the photographs of failure (see *Figs.* 12 and 13).

As regards adhesion, we have at working loads—

$$\text{Total tensile force} = 2{\cdot}44 \times 10{,}740 = 26{,}200 \text{ lbs.}$$
$$\text{Area in adhesion} = 2 \times \pi \times 1{\cdot}25 \times 54 \text{ in.} = 424 \text{ ins.}^2$$
$$\text{Adhesion stress} = \frac{26{,}200}{424} = 62 \text{ lbs./in.}^2$$

This being well below the usual safe value (100), it follows that at ultimate conditions the adhesion stress was correspondingly below the ultimate value, the factor actually being

$$4{\cdot}9 \times \frac{62}{100} = 3{\cdot}0$$

as against the factor 4·9 in compression.

It is of interest to consider the question of buckling of the compression bars by comparing the actual stresses in them as determined by method (*a*) (see Table IV.) with the safe L.C.C. stresses for mild steel pillars for the same ratio of length to radius of gyration, taking the length as the spacing of the stirrups (9 in.).

TABLE VII.

Comparison of Stress in Compression Steel with L.C.C. Stresses for M.S. Pillars.

Beam Number.	Size of Beam.	Length/ Radius of Gyration.	Safe Stresses, L.C.C.			Actual Stress.
			Both Ends Free.	One End Fixed.	Both Ends Fixed.	
	in.					
9	$\frac{1}{2}$	72·0	6,040	8,280	10,500	2,860
10	$\frac{5}{8}$	57·6	6,830	9,070	11,300	4,390
11	$\frac{3}{4}$	48·0	7,390	9,630	11,870	5,500
12	$\frac{7}{8}$	41·1	7,760	10,000	12 260	5,750
13	1	36·0	8,060	10,300	12,540	5,940
14	$1\frac{1}{8}$	32·0	8,280	10,550	12,770	6,080
15	$1\frac{1}{4}$	28·8	8,450	10,700	12,940	6,190
16	$1\frac{3}{8}$	26·2	8,620	10,850	13,100	6,300

The writer would consider the compression bars as having both ends fixed, or nearly so, since, if we consider a length between two stirrups tending to buckle upwards, the concrete would prevent the bars from deflecting downwards in the two adjacent panels, and at the stirrups the inclination would remain zero.

It will be seen that the safe L.C.C. stresses (ends fixed) are about twice the actual stresses in the rods, but are much less than the stress of 16,000 which is assumed in method (*b*).

When we take into account the fact that the longitudinal compression of the concrete causes an upward swelling (in accordance with Poisson's ratio), it is clear that the bar is subjected to an initial bending moment, making the conditions for buckling more severe. For this reason the writer would conclude that the stress of about 6,000 in the compression bars, besides being about correct from the point of view of the modulæ ratio, is also not very far from the truth when buckling under these conditions is taken into account with stirrup spacings common in practice.

ANNUAL GENERAL MEETING.

We give below a Summary of the Report of the Concrete Institute for the year 1915-1916, which was presented at its Seventh Annual Meeting held on May 17th.—ED.

A SUMMARY OF THE REPORT OF THE COUNCIL.

THE present membership of the Concrete Institute and the alteration since the previous figures were given in the Report for the 1914-15 Session is 1,002.

The finances of the Institute are shown in the balance-sheet which accompanied the Report. In 1913, 1914, and 1915 there were deficits.

The number of general meetings has been reduced, and in view of many of the junior members joining the Forces the educational lectures and the informal meetings of junior members have again been abandoned for the Session; such educational work will be resumed in the future.

Award of Institute Bronze Medal.—As the result of a ballot among members of Council, the bronze medal for the best paper read in the 1914-15 Session has been awarded to Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., etc., for the paper entitled "The Design of Quay Walls."

L.C.C. Regulations.—The Regulations made under the provision of Section 23 of the London County Council (General Powers) Act, 1909, with respect to the construction of buildings wholly or partly of reinforced concrete, to the amendment of which the Council and Committees of the Institute have given much attention in former years, came into force on January 1, 1916.

Scientific Research.—The Institute was asked by the Advisory Council appointed by the Committee of the Privy Council for Scientific and Industrial Research to co-operate by furnishing a statement indicating the specific problems, requiring scientific investigation, of the industries with which this Institute is most intimately concerned. The matter was considered by the Science Standing Committee and the Council who submitted a list of subjects for research, and in the covering letter it was pointed out that the research work in this country, upon the design and construction of structures, more particularly those of concrete, reinforced concrete and steel, had been sporadic and of minor value to practical work, because, quite apart from lack of funds for such work, there had been lack of co-ordination and control by those who would be engaged in the practical application of the knowledge sought from such research. For instance there had been very few tests of real utility to designers of reinforced concrete, though that was one of the new modes of construction whose application had been widely extended of recent years. Most of the information available to designers had been derived from experiments conducted in France, the United States, and Germany, but seeing that such experiments had largely been framed in view of special local conditions, they did not generally directly apply to practice in this country.

After reference to the occupation and number of members of the Institute, the offer was made of the services which it was hoped the Advisory Council would require of the Institute, namely, advising in detail on tests of practical utility to the structural engineer; in addition the offer was made of any assistance in the way of supervision of the ways and means of research which the Advisory Council might entrust to the Institute's Council. In reply the Research Council invited the representatives of the Institute to meet their Chairman, Sir William M'Cormick, and the following attended: Professor Henry Adams, President C.I., M.Inst.C.E., etc.; Mr. E. P. Wells, J.P., Past President C.I.; Mr. H. D. Searles-Wood, Vice-President C.I., F.R.I.B.A.; Mr. R. H. Harry Stanger, Assoc.M.Inst.C.E.; and the Secretary, Mr. H. Kempton Dyson. The Institute is now engaged in formulating detailed particulars in respect to an application for a grant in aid of researches that can be immediately undertaken by various laboratories and engineering institutions on a co-ordinated scheme.

Relation of Architects and Reinforced Concrete Specialists.—The Council of the Concrete Institute have appointed the following as a Special Committee to consider and report on the relations of the architect and the reinforced concrete specialist and structural engineer:—

Sir Henry Tanner, C.B., I.S.O., F.R.I.B.A.; Prof. Henry Adams, M.Inst.C.E., Pres. C.I. (*ex officio*); Dr. Oscar Faber, D.Sc., Assoc.M.Inst.C.E.; Mr. H. D. Searles-Wood, F.R.I.B.A., Vice-Pres. C.I.; Mr. T. B. Shore; Mr. R. W. Vawdrey, B.A., Assoc.M.Inst.C.E.; and Mr. H. Kempton Dyson (Hon. Secretary).

The District Surveyors' Association asked the Institute to nominate representatives upon a Conference on the working of the London County Council (General Powers) Act, 1909, with reference to steel frame buildings. The members of the Conference are as follows:—

Representatives of the Royal Institute of British Architects—Mr. F. R. Farrow, F.R.I.B.A. (*Chairman*); Mr. W. E. Vernon Crompton, F.R.I.B.A.; Mr. F. N. Jackson, Assoc.M.Inst.C.E., Hon. A.R.I.B.A., M.C.I.

Representatives of the District Surveyors' Association—Mr. Arthur Ashbridge, F.R.I.B.A.; Mr. Bernard J. Dicksee, F.R.I.B.A.; Mr. E. Alexander Young, A.R.I.B.A.

Representatives of the Concrete Institute—Mr. S. Bylander, M.C.I.; Mr. E. Fiander Etchells, Assoc.M.Inst.C.E., Hon. A.R.I.B.A., F.Phys.Soc., M.C.I., etc.; Mr. W. G. Perkins, M.C.I., District Surveyor for Holborn.

The Hon. Secretary—Mr. H. Kempton Dyson, Secretary C.I.

Examinations.—The rules and syllabus of the proposed examination of the Concrete Institute were appended to a previous report of the Council. The first examination is deferred until after the war.

Member Deceased.—The Council regrets to record the decease of: Killed in action, Lieutenant J. Hopkinson.

The Library.—Several donations to the Library have been received by the Council from authors, publishers, and kindred societies, and the Council expresses thanks to the donors. A list of books received is published from time to time in the *Transactions*.

THE WORK OF THE SUB-COMMITTEES.

Finance and General Purposes Committee.—The Finance and General Purposes Committee has held regular meetings preliminary to each Council meeting, and the general results of their deliberations are contained in the foregoing particulars of the Council's work for the year.

Science Standing Committee.—As the outcome of a resolution of the joint meeting of the Science and Tests Standing Committees the Council decided to combine the two Committees under the name of the Science Committee. The appointment of the members of the separate Committees was therefore rescinded, and the following were then appointed members of the newly constituted Science Committee:—

Chairman—Mr. H. D. Searles-Wood; *Vice-Chairman*—Mr. W. G. Perkins; *Hon. Secretary*—Mr. M. E. Yeatman; *Ordinary Members*—Professor Henry Adams, Mr. Ewart S.

Andrews, Mr. H. K. G. Bamber, Professor T. Hudson-Beare, Mr. D. B. Butler, Mr. E. Fiander Etchells, Dr. O. Faber, Mr. J. E. Franck, Mr. M. Garbutt, Mr. H. C. Johnson, Mr. Charles F. Marsh, Dr. J. S. Owens, Mr. A. R. Sage, Mr. R. H. Harry Stanger, Mr. R. W. Vawdrey, Mr. E. P. Wells, and Mr. F. E. Wentworth-Sheilds.

The Committee has formulated a list of subjects for research which has been referred to above under the work of the Council, and has begun to consider the various suggestions that have been made for the amendment of the Building Acts throughout the country.

The Science Standing Committee has the following matters under consideration :—

1. Amendment of the London Building Acts and Building By-laws generally.
2. Standardisation of joints and connections in reinforced concrete.
3. Amendment of the Standard Specification for cement.
4. Co-ordination of the Standard Specifications for structural steel of all kinds.

Reinforced Concrete Practice Standing Committee.—This Committee has not held any further joint meetings with delegates of the Quantity Surveyors' Association in reference to the report on a Standard Method of Measurement for Reinforced Concrete except to revise the report in view of the discussion and get it finally approved as regards building construction by the Councils of the two Societies concerned. The first part of the report, namely, that dealing with building construction, has been published by the Quantity Surveyors' Association, but the Concrete Institute is deferring publication of the report until it has been completed by a section dealing with Quantities for Engineering Work.

The Committee has in hand the drafting of a report on the Supervision of Reinforced Concrete Work containing recommendations which it is to be hoped will be helpful to inspectors, clerks of works, and foremen as regards the execution.

The Reinforced Concrete Practice Standing Committee has the following matters under consideration :—

1. Advice to clerks of works, inspectors, and foremen as to methods of properly executing concrete work and of preventing defects and failures.
2. Regulations, recommendations of joint committees, and various methods of calculation in respect to the design of reinforced concrete and the like.
3. Standard concrete mixtures for general purposes.
4. The use of cinder, ash, clinker, and breeze in concrete.
5. Methods of making concrete watertight and of waterproofing concrete.

Parliamentary Standing Committee.—The Parliamentary Standing Committee has the following matter under consideration :—

The draft of a Bill promoted by the Society of Architects for the registration of architects.

Investigation Committee.—The Investigation Committee has had under consideration reports of a failure of a reinforced concrete structure, but as the information contributed was confidential, the results of their deliberations cannot be furnished in the form of a report.

Joint Committee on Loads on Highway Bridges.—The Joint Committee on Loads on Highway Bridges convened by the Institute submitted their draft report for discussion at a general meeting.

It is completed, and will shortly be issued in separate form.

THE ANNUAL GENERAL MEETING.

THE Annual General Meeting of the Institute was held at Denison House, Vauxhall Bridge Road, S.W., with the outgoing President, Professor Henry Adams, in the chair. After the adoption of the Report, the Institute's Medal was presented to Mr. F. E. Wentworth-Sheilds for his paper on "The Design of Quay Walls on Earth Foundations." Mr. F. E. Wentworth-Sheilds was also elected President to succeed Professor Henry Adams. We give below a short summary of the proceedings.

DISCUSSION.

The President, in moving the adoption of the Report and Balance-sheet, said there was a small but not very serious reduction in the membership, but that was not to be wondered at considering the circumstances of the war and how it had influenced their business in every direction. A reduction had been made in the number of general meetings, at which had been a very good attendance. The chief work done by the Institute during the past year had been the completion of the London County Council Regulations for Reinforced Concrete. The Loads on Bridges Report had been completed, but it had not yet been finally passed for issue. On the Finance and General Purposes Committee Mr. Fiander Etchells had taken the place of Mr. Searles-Wood as chairman. In the balance-sheet it would appear that the expenditure had been slightly in excess of the receipts for each of the last three years, but the adverse balance had been reduced and was now very small. The next important work they had in hand was the report on advice to clerks of works, inspectors and foremen as to methods of properly constructing concrete work and of preventing difficulties and failures. There had been special meetings in connection with that, and they had almost completed the report. It was of the utmost importance, because efficient workmanship was the criterion of reinforced concrete practically.

Mr. H. D. Searles-Wood, F.R.I.B.A., Vice-President, seconded, and the report and balance-sheet were approved.

PRESENTATION OF THE INSTITUTE'S MEDAL.

The President then presented the Institute's medal for the best paper of the session to Mr. Wentworth-Sheilds for his contribution to their Transactions on the "Design of Quay Walls on Earth Foundations." The subject might have been treated from a purely theoretical point of view, but the paper was essentially practical and contained much information that engineers knew but did not always impart.

ELECTION OF PRESIDENT.

The President moved the election of Mr. Wentworth-Sheilds as his successor in office. He regretted the termination of the period of his own service, but there was satisfaction in knowing that there was a better man to follow him. He said he was a good practical engineer, specially versed in reinforced concrete, and in every way suitable for President. He trusted they would accord to his successor the help and sympathy they had extended to himself during the last two years.

Mr. Wentworth-Sheilds took the chair and returned thanks for his election. He said he was deeply sensible that he took office at a very important time for them all. They were now in the shadow of the most colossal war that had ever been known. In spite of that, or he might say because of that, the whole nation and the Empire were beginning to recognise the importance of scientific work in every branch of life, and societies like theirs were called upon to do most important work and to take a most important position at this time. The nation called to them to emphasise the need for scientific investigation, scientific training, and scientific practice, and more than any other organisations, societies like theirs could do very much to promote the growth of these three important things, and thereby to bring about efficient and good work, which would be not only for the benefit of their profession, but for the benefit of their country and of their Empire. Therefore, he said, it was with a full sense of the responsibility of the work of their society that he now took office. The country called to them to do a great work, and he was sure there was not a member of the Institute who would shrink from it.

Mr. E. Fiander Etchells was elected a Vice-President.

THANKS TO THE RETIRING PRESIDENT.

Mr. H. D. Searles-Wood, in moving a vote of thanks to Professor Adams, the retiring President, said they had had the advantage during the past two years of a man of the highest professional attainments and of most excellent business qualifications, and his reputation had been of immense benefit to the Institute.

Mr. Morgan E. Yeatman, M.A., seconded.

Professor Adams then made a short reply, which terminated the proceedings.

View of Portion of a Regimental Camp.

CONCRETE SLABS FOR MILITARY CAMP.

In recent issues we have dwelt upon the use of concrete for military hutments, and in the following article we are able to publish some interesting particulars regarding a large encampment which has been constructed largely in this material.—ED.

WAR conditions have brought about many changes in connection with building methods, owing to lack of labour and difficulties in obtaining building materials for use in the erection of buildings on lines adopted in pre-war times.

One of the most improved methods of building construction has been adopted by the engineers in charge of the erection of a large military camp in this country, where, instead of constructing the buildings with timber, corrugated iron, lath and plaster, or other materials, recourse has been had to the construction of a large part of the camp with concrete slabs and blocks in combination with a light steel-work skeleton frame.

This camp is situated close to a valley, and the existing bed of the stream and portions of the valley bottom, which probably was at one time on the line of the stream, contain large quantities of excellent sand and gravel of a character especially suitable for use as an aggregate for concrete. The engineers for the scheme very wisely decided to use this material on the job, and have utilised the larger boulders for road making, the medium sized for *in situ* concrete, and the smaller sizes and sand for the manufacture of concrete blocks and slabs for the erection of hutments, and the methods used are such that a full description of them will, we think, be of interest to our readers. The consulting engineers for the scheme are Messrs. Harper Bros. and Co., of St. Helen's Place, London; Mr. R. B. Waite, C.E., acting as their engineer in charge on the spot. He has handled 1,000 tons of aggregate per day for concrete making since the start of the work.

CONSTRUCTION.

After the positions of the buildings had been pegged out the turf was stripped from the site of each building by means of a turf-cutting machine.

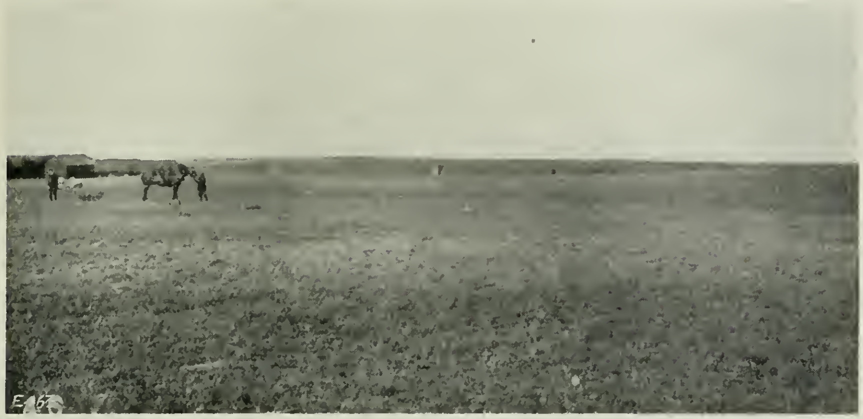


Fig. 1. Stripping the Turf.

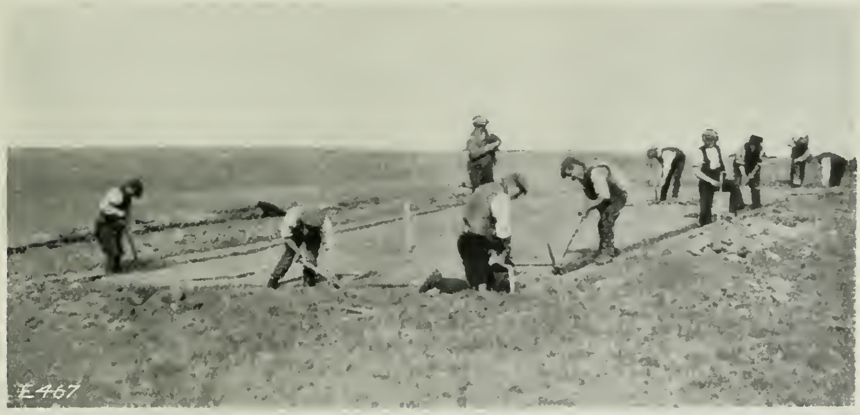


Fig. 2. Digging the Foundations.
CONCRETE SLABS FOR MILITARY CAMP.

Excavations.—The necessary excavations were next taken in hand for the *in situ* concrete footings to walls and for the bases of the steel stancheons.

Supports.—The rolled steel stancheons, to which are fixed light steel trusses, were next placed in position and the lower ends embedded in concrete, and the timber purlins fixed to the roof trusses to steady the framework.

Erecting Steelwork.—From *Fig.* 3 it will be noticed that the only steelwork used is for the light rolled steel stancheons, supporting the ends of simple framed steel roof trusses. After the steelwork is fixed concrete blocks, 28$\frac{1}{2}$ in. by 9 in. by 7 in., are laid upon the *in situ* concrete foundations and brought up to floor level. From this point upwards the walls are built with concrete slabs, 2$\frac{3}{16}$ in. in thickness, 28$\frac{1}{2}$ in. long by 9 in. high, the end joints being moulded so as to interlock.

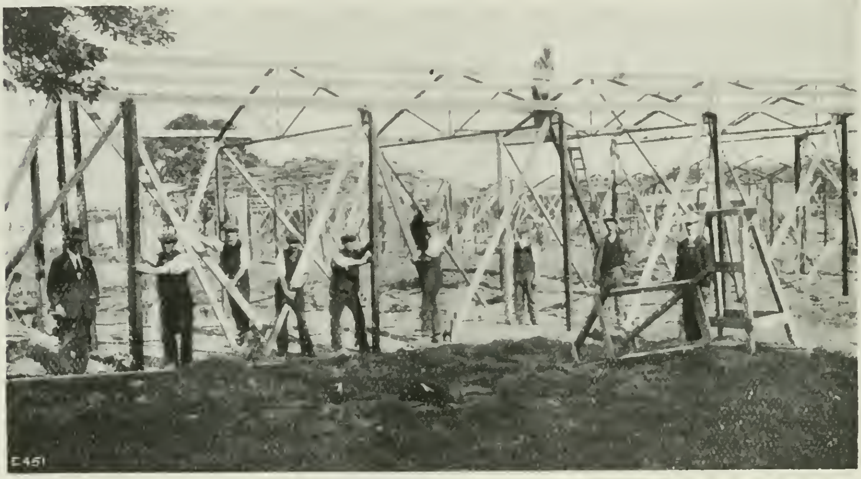


Fig 3. Erecting Steelwork.

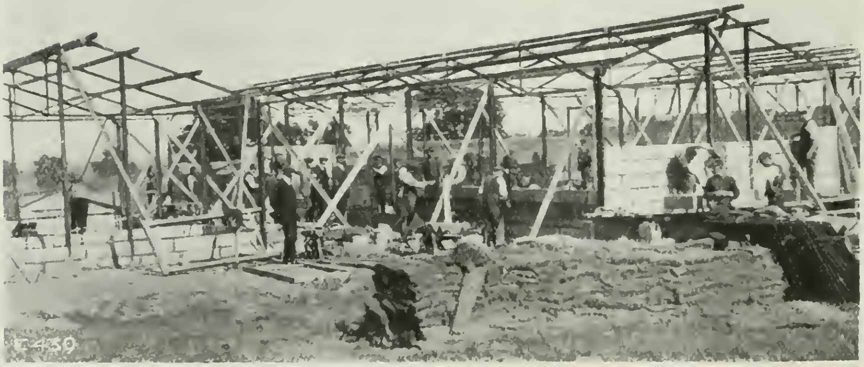
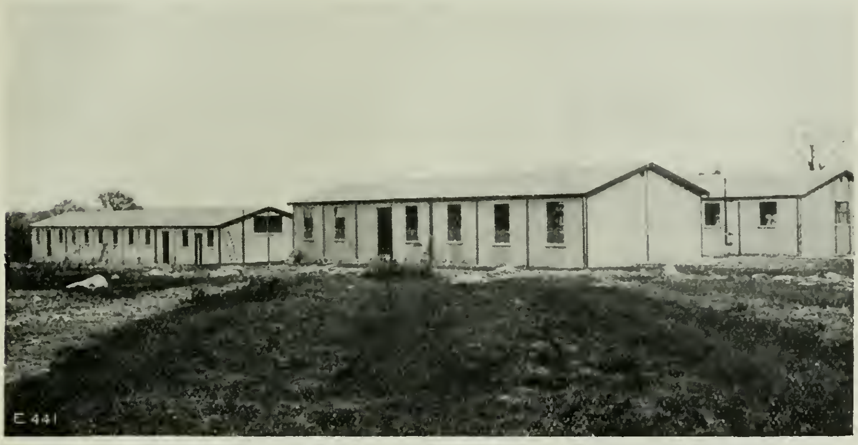
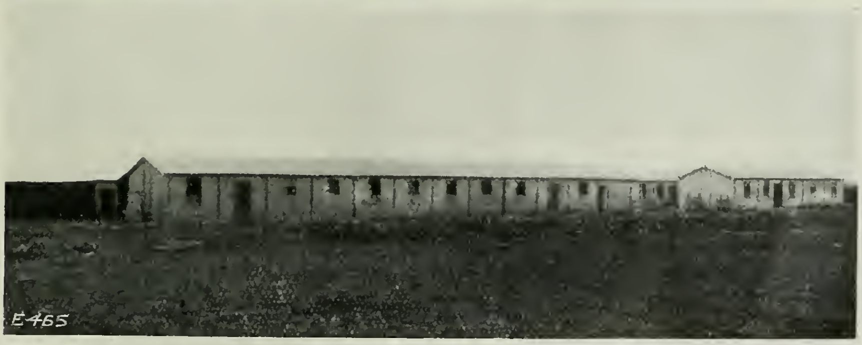


Fig. 4. Erecting the Concrete Slabs.
Concrete Slabs for Military Camp.

Erecting Slabs.—In the above view it will be seen how the thin slabs are fixed so as to fit in between the flanges of the stancheons. They are walled in cement mortar. On the completion of the walling the exterior of the building is rendered with cement mortar, made weatherproof by the addition of a waterproofing compound. On the inside face of the walls the joints are neatly pointed, and receive no further treatment, except that they are colour washed in various agreeable tints.

Casements, Roofing.—The windows are all steel frame with hopper fanlights. The roofs are of timber covered with felt, and the floors are either P.T. & G. boards or asphalt, on corrugated sheeting, all on timber joists. Although the construction of the buildings is very light, they have proved to be remarkably strong in practice and have withstood extremely strong gales and bad weather quite satisfactorily.





Figs. 5 and 6. Officers' Quarters, Officers' Mess, Stores Huts, etc.

Concrete Slabs for Military Camp.

THE BUILDINGS.

The buildings are, of course, of very varied character, and comprise all the accommodation required in connection with camps.

They comprise officers' quarters (100 ft. by 20 ft. by 8 ft. 6 in.) as above; officers' mess (140 ft. by 20 ft. by 8 ft. 6 in.); stores quarters (60 ft. by 20 ft. by

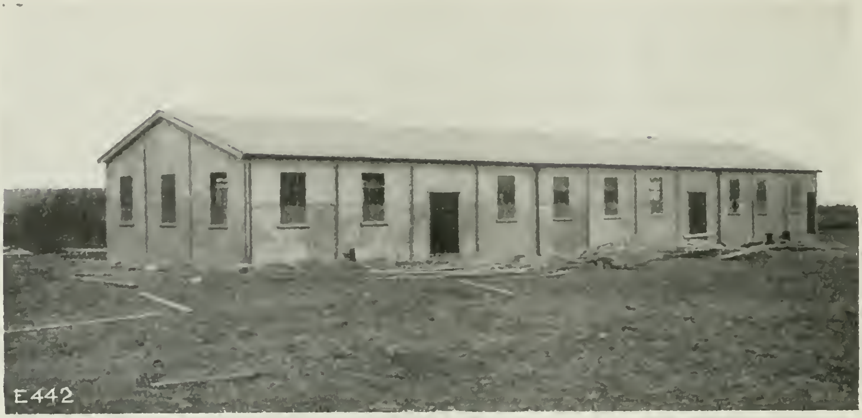


Fig. 7. Regimental Institute.
(190 ft. by 28 ft. by 10 ft. 6 in.)

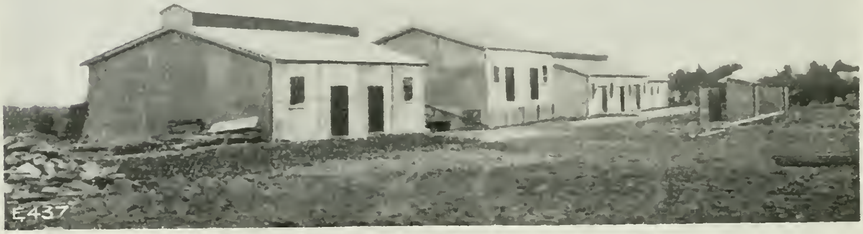


Fig. 8. Bread, Flour and Meat Stores, and A.S.C. Office.

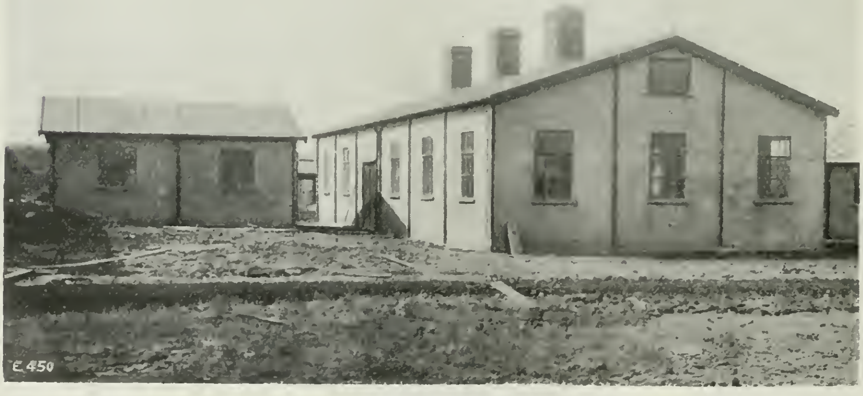


Fig. 9. Cook House and Wash-up.
(60 ft. by 8 ft. by 10 ft. 6 in. and 20 ft. by 20 ft. by 8 ft. 6 in. respectively.)
Concrete Slabs for Military Camp.

8 ft. 6 in.); religious purposes huts; barrack huts (60 ft. by 20 ft. by 8 ft. 6 in.); ablution sheds (40 ft. by 20 ft. by 7 ft.); latrines; cook houses; bakeries; wash-up houses; dining-rooms (110 ft. by 28 ft. by 10 ft. 6 in.); bath houses; heating apparatus chambers; harness rooms; guard houses and offices; sergeants' mess (50 ft. by 20 ft. by 8 ft. 6 in.); sergeants' institute (70 ft. by 20 ft. by 8 ft. 6 in.); regimental institute; institute annexes (40 ft. by 20 ft. by 8 ft. 6 in.); company offices; barrack expense stations; rifle ranges; stables; horse shelters; post office buildings; and A.O. buildings.

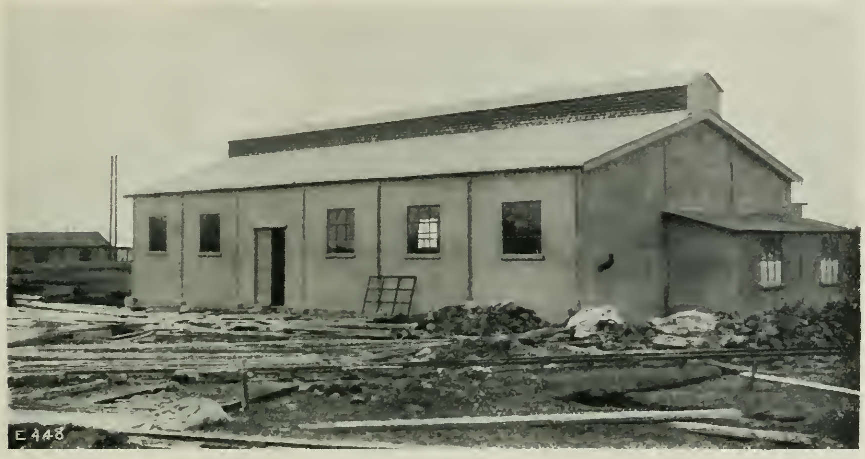


Fig. 10. A Bakery.

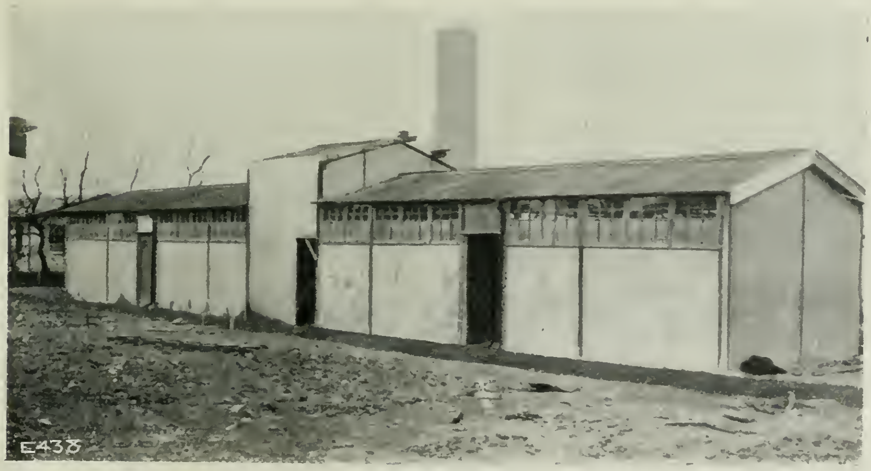


Fig. 11. A Bath House.
(24 ft. by 15 ft. by 10 ft.)

Concrete Slabs for Military Camp.

The foregoing schedule and illustrations comprise a complete camp.

The standard barrack hut (*Fig.* 12) is, of course, the most in evidence.

Conclusion.—This is a large military camp erected during the period of the war. The huts in practice have been found to be perfectly weather-tight and extremely comfortable in use. They are stated to have cost less than huts of similar size built of timber, and are considered by the Army Authorities to be better for their purpose than any hitherto constructed. They have many advantages over timber huts, seeing that the walls are fireproof, and are not subject to deterioration, and require no upkeep. The walls afford no harbourage for vermin, and, being only $2\frac{3}{4}$ in. thick, take up little space.

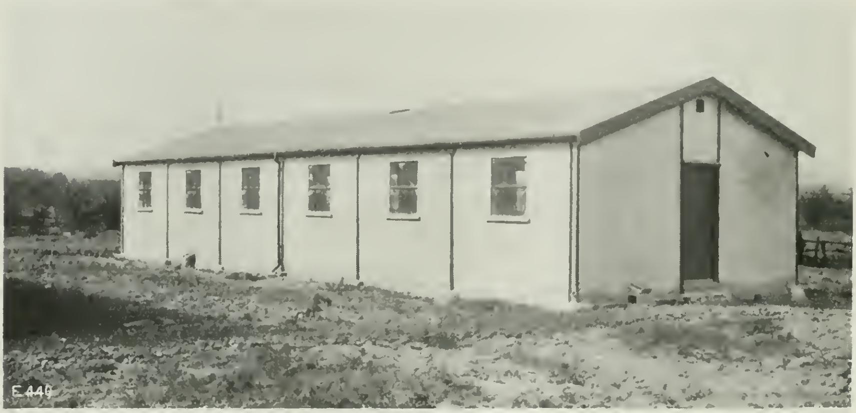


Fig. 12. A Barrack Hut.
(60 ft. by 20 ft. by 8 ft. 6 in.)

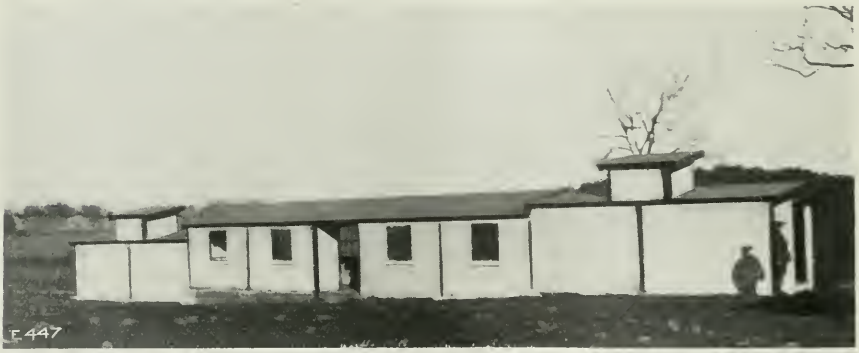


Fig. 13. The Latrines.
(44 ft. by 10 ft. 6 in. by 7 ft.)
Concrete Slabs for Military Camp.

The slabs and foundation blocks have all been made on machines supplied to the War Department by Winget, Limited, and *Fig.* 14 shows a stacking ground, where a number of "Winget" machines are at work on a portion of the contract making slabs. The extent of the job may be gathered from the fact that the output of the machines supplied is equal to producing 33,000 "Winget" slabs, 28½ in. by 9 in. by 2$\frac{3}{16}$ in., per day.

The contractors who have carried out the work above are Messrs. Henry Boot and Sons, Ltd., Sheffield, and Messrs. Sykes and Son, Ltd., London, the total value of their contracts being approximately £150,000.

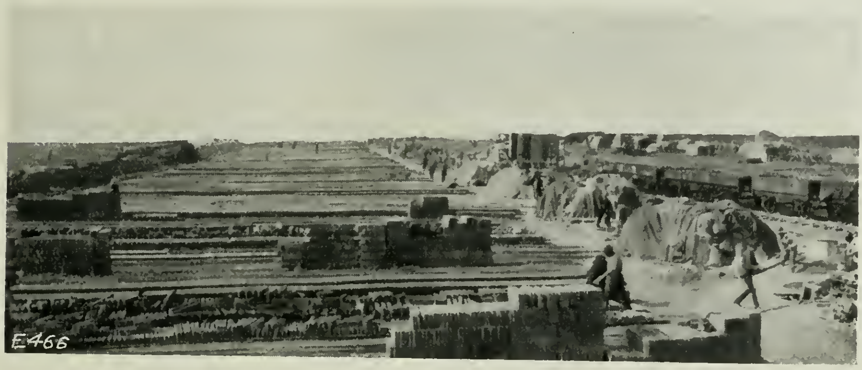


Fig. 14. Stacking Ground for "Winget" Machine-made Slabs and Blocks.
Concrete Slabs for Military Camp.

RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

THE SECOND NATIONAL CONFERENCE ON CONCRETE ROAD BUILDING, U.S.A.

A CODE FOR THE CONSTRUCTION OF CONCRETE ROADS.

At the above Conference, held early this year, a code of practice was recommended for the construction of concrete roads and pavements, and we give this code below.

In the following code each division of the work is taken up, and the views as to best practice, as presented in committee reports and developed in the discussion, are set forth briefly; as is natural most of the code is devoted to aggregates, methods of mixing and placing, and such other details as are most likely to affect for better or worse the concrete pavement. Controversial matters are avoided.

The code adopted is as follows:—

1.—Specifications.

Since no specifications were considered by the Conference the Standard Specifications for Pavements and Roadways of the American Concrete Institute are recommended.

2.—Drainage.

The drainage of the road-bed is of vital importance. If the subgrade is not well drained, there is danger of unequal settlement or frost action, which will cause cracks. The method of drainage to be used will depend on local conditions. For roads proper drainage may be secured through lateral ditches. For streets, as well as roads, tile drains may be used which should be laid on each side of the roadway, or on one side only, with cross drains leading thereto at a suitable depth, depending on the width of the pavement. Drainage trenches, if placed under the subgrade, should be completed before final rolling.

3.—Grading.

When roadways are constructed over fills extreme care should be observed to ensure the use of proper materials in layers of such thickness that they may be thoroughly compacted so that when the fill is completed there will be a minimum of settlement. In general, fills shall be made in thin layers, the depth depending on the character of material to be used in making the fill. The fill should be allowed to stand for as long a time as possible, giving it an opportunity to settle thoroughly before the pavement is placed thereon. Deep fills should be allowed to settle through one winter wherever such procedure is possible. Puddling will be found advantageous in compacting deep fills. Wetting and rolling shall be performed when making a fill in order to secure thorough compactness. Fills should never be made with frozen materials nor with lumps greater than 6 in. in their greatest dimension.

4.—SUBGRADE.

The fundamental requirement of the subgrade is that it should be of uniform density so that it will not settle unevenly and cause cracks in the surface of the pavement. No part of the work is more worthy of intelligent care and painstaking labour than the preparation of the subgrade. The slight additional cost necessary to ensure good results is abundantly justifiable. When the pavement is constructed on virgin soil, care should be taken to remove all soft spots so as to ensure a uniform density; and if constructed on an old road-bed, even greater care must be taken to secure uniform density, as the subgrade is likely to be more compact in the centre than at the sides. An old road-bed should be scarified, re-shaped and rolled. The subgrade adjacent to kerbs should be hand-tamped.

5.—MATERIALS.

Portland Cement.—Portland cement shall meet the requirements of the standard specifications for Portland cement of the American Society for Testing Materials, and tests should be made in accordance with the methods of tests outlined by the American Society of Civil Engineers.

Aggregates.—The selection of proper aggregates for concrete road construction is of utmost importance. Clean, hard, well-graded materials are absolutely essential to success. For this reason samples of the materials proposed for use should be submitted to the engineer for approval before orders are placed. These samples should be carefully inspected; and, if possible, laboratory tests made to determine their suitability. If laboratory tests on shipments cannot be made, field tests can be used to furnish a general indication of quality.

The different aggregates should be kept clean and separate.

Aggregates to be used in the wearing course of two-course pavements should never be placed on the subgrade but on planks or some other means provided to keep them free from dirt. When aggregates are placed directly on the subgrade care should be used by the shovellers to avoid getting clay or earth shovelled from the subgrade into the mix. Aggregates should not only be clean when they are delivered on the job, but clean when placed in the mixer.

Water.—Water supply is a most important factor and is frequently overlooked by the engineer and contractor. A large supply of water is necessary for (*a*) sprinkling the subgrade; (*b*) mixing the concrete; and (*c*) keeping the concrete moist during early stages of hardening. For this latter purpose 25 to 30 gal. per sq. yd. of pavement will be required during the summer months. Insufficient sprinkling is detrimental to the wearing qualities of the pavement.

Reinforcement.—The use of reinforcement in concrete pavements is increasing. A coating of light rust will not be detrimental to satisfactory results, but care should be exercised that no excessive rust, paint or other coatings are present to interfere with proper bond. Care should also be exercised to see that the reinforcement is so stored, prior to use, that it is not covered with mud or clay when placed in the pavement. Reinforcement left on a job when contract is not completed at the end of the season should be collected and stored so that it is protected from the elements. Occasional tensile and bending tests should be made to see that the requirements of the specifications are fulfilled.

Joint Filler.—Joint filler should preferably be of a single thickness. Transverse joint filler should be cut to the crown of the pavement by the manufacturer when metal plates are used. A type of joint filler which will iron out readily under traffic is preferable for use in unprotected joints. A joint filler which will not bend easily when concrete is deposited against it is to be preferred.

Joint-Protection Plates.—Metal joint-protection plates should be properly bundled and wired by the manufacturer so that they will arrive on the work in good condition, free from warp. Protection plates up to 20 ft. shall be shipped in single lengths. The exact length should be provided so that the contractor will not find it necessary to cut plates In cutting plates for length, spacing between eccentrics on the installation bar should be considered to avoid interference with anchorage lugs on plates. Particular care should be used by the manufacturer in crowning the installing bar, to avoid the necessity of duplication of work by the contractor.

6.—FORMS.

Metal forms of sufficient strength to withstand the necessary hard usage are preferred. When wooden forms are used they should be of at least 2-in. stock and capped with a 2-in. angle iron, so constructed that adjacent sections can be lapped. Forms should have a width not less than the thickness of the pavement at the sides. Particular care should be exercised to see that the top edge of forms are clean so as to avoid unevenness in the finished pavement. If forms are warped or stakes not properly placed, a poor alignment of the edge of the concrete slab will result.

7.—PAVEMENT SECTION.

Thickness.—The thickness of a concrete road or pavement is controlled by many factors, each of which should be given consideration. In view of the increasing use of the heavy motor truck and bus, it seems unwise to build pavements with a thickness of less than 6 in. at any point. In general, pavements shall be thicker at the centre than at the sides. Alleys with an inverted crown and narrow one-slope roads should have a uniform thickness. Wherever the thickness can be increased without excessive cost, to secure a flat or nearly flat subgrade, such increase is advisable.

Width.—The desirable width for single-track road is 10 ft. The desirable width of double-track roads is 18 ft. The total width of the roadway should not be less than 20 ft. for single-track roads and not less than 26 ft. for double-track roads.

Crown.—The crown of roads and pavements should be not less than one-hundredth nor more than one-fiftieth of the total width. Except in unusual cases, one one-hundredth will be sufficient for country roads and one-fiftieth will be considered satisfactory for alley pavements. For city streets an average crown of one-seventy-fifth will generally be found sufficient and should not be reduced, except on grades.

8.—JOINTS.

Transverse Joints.—Joints should be placed across the pavement perpendicular to the centre line about 50 ft. apart.

There seems to be a tendency to widen the distance between joints.

Joints should extend entirely through the pavement as well as through the kerb if integral kerbs are used. Joints should be constructed perpendicular to the surface of the pavement to avoid the possibility of one slab rising above the other.

Longitudinal Joints.—Longitudinal joint filler should be staked or otherwise securely held against the kerb. Joint material should also be placed around manholes, catch-basins, etc.

Protected Joints.—The tendency of present practice is towards the omission of metal protection plates for joints. It is possible that the value of metal protection plates is dependable somewhat on the character of aggregate used, and it is considered that they are more essential in street pavements than in country highways.

Plates.—Plates for protected joints should be wired together with the joint filler in place and securely held in the installing bars. When short sections of joint filler are used they should likewise be wired together. Supports for the joint should be used when the pavement is of such width that the installing bar deflects. On wide streets every joint should be checked as to crown with sighting T's. When necessary to have joint plates in two sections, the contractor should arrange with the manufacturer to have holes drilled in the abutting ends of the plates so that the plates may be securely wired or strapped together. As the joint plates usually do not fit tight to the installing bar, a $\frac{1}{4}$-in. shim is placed under each end of the installing bar, to ensure that the plates are not covered by the concrete.

9.—MIXING AND PLACING CONCRETE.

Measuring.—The method of measuring materials for the concrete, including water, should be one which will ensure accurate proportions of each of the ingredients at all times. It is recommended that a sack of Portland cement, containing 94 lb. net, be considered the equivalent to 1 cu. ft.

Proportioning.—The proportions should not exceed five parts of fine and coarse aggregate measured separately to one part of Portland cement, and the fine aggregate should not exceed 40 per cent. of the mixture of fine and coarse aggregates.

Aggregates.—Bank run material should not be used. Proportioning based on sieve analysis or by relative density tests is not practicable for concrete roads, except where laboratory direction is available; but where proper facilities are available the above proportions should be varied as the tests warrant.

Mixing.—The ingredients should be mixed in a batch mixer of approved style, and the size of the batch should not exceed the rated capacity of the mixer. The mixing should be continued for at least 1 minute after all the materials are in the mixer and before any of the concrete is discharged. The speed of the mixer should not exceed 16 revolutions per minute; however, the time and not the number of revolutions should be the gauge of proper mixing.

Consistency.—The practice is to mix concrete entirely too wet. The consistency should be such as not to require damping, but not so wet as to cause the separation of the mortar from the aggregate in handling and placing. The strength and wearing qualities of the concrete are vitally lessened by an excess of water in mixing.

Placing.—If the subgrade has been disturbed by teaming or other causes, it should be brought to its former surface, and thoroughly saturated with water. The concrete should be deposited rapidly to the required depth and width. The section should be completed to a transverse joint, without the use of intermediate forms or bulkheads, or a transverse joint may be placed at the point of stopping of the work. In case the mixer breaks down the concrete should be mixed by hand to complete the section. Where reinforcement is used it should be embedded in the concrete before the concrete has begun to set; the concrete above the reinforcement should be placed within 20 minutes after the placing of the concrete below.

In two-course pavements the top should be placed within 20 minutes after the placing of the bottom.

Finishing.—The surface of the concrete should be struck off by means of a template moved with a combined longitudinal and transverse motion. The excess material accumulated in front of the template should be uniformly distributed over the surface of the pavement except near the transverse joint, where the excess material should be removed.

The concrete adjoining the transverse joint should be dense, and any depressions in the surface should be filled with concrete of the same composition as the body of the work. After being brought to the established grade with a template, the concrete should be finished, from a suitable bridge, with a wood float to true surface. A metal float should not be used.

Brooming of the surface is not necessary and grooves are objectionable even on grades.

10.—RETEMPERING.

Retempering of mortar or concrete which has partially hardened—that is, mixing with additional materials or water—is strongly condemned and should not be permitted.

11.—PROTECTION AND CURING.

Even the best concrete may be seriously damaged by too rapid drying out, early exposure to low temperature or by being opened to traffic at too early a period. Hot sun and drying winds are most liable to dry out the concrete too rapidly, thus causing shrinkage cracks or causing a surface which will not wear well under traffic. The use of a canvas covering will be found effective in overcoming this condition.

Sprinkling should also be employed as soon as the concrete is hard enough to prevent the surface being pitted. An earth covering or protection by ponding should be employed after the first day. Under most favourable conditions such protection should be given the pavement for at least two weeks. Water should be added during this period to keep the concrete wet.

In cool weather it is often advisable to omit the earth covering, thus allowing the concrete to harden more rapidly. Sprinkling should not be omitted during the day in case the surface shows a tendency to dry out. When there is danger of frost, sprinkling should be omitted and a covering of canvas or straw and canvas used.

Placing concrete in roads and pavements in temperatures at or near freezing is not advisable, and if in special cases such work is unavoidable, the water and aggregate should be heated and precautions taken to protect the concrete from freezing for at least ten days. Chemicals to lower the freezing temperature of the mixture should not be used.

Concrete should not be deposited on a frozen subgrade.

12.—Opening to Traffic.

Under most favourable conditions a concrete pavement should not be opened to traffic in less than two weeks, and, when conditions permit, this interval should be at least four weeks.

13.—One-Course Pavement.

Where the materials most readily available are such as to give good construction in one-course pavement, this convention recommends that the one course be used.

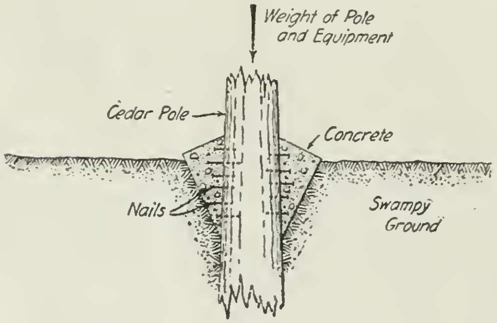
14.—Integral Kerb.

The integral kerb for concrete street pavements is recommended in preference to straight kerb or combined kerb and gutter. Such construction eliminates the longitudinal joint along kerb, maintains a permanent grade and alignment. Precaution should be taken to ensure that the kerb is thoroughly bonded to the pavement proper. The integral kerb can be used on wide as well as narrow streets.

MEMORANDUM.

Concrete Collars Economical Support for Poles in Swamp.—The builders of an Ohio transmission line which crossed swampy ground overcame troubles due to settlement of the poles by the expedient illustrated in the accompanying drawing. Poles of this sort carry loads much greater than their own weight, due to tension in the lines stretched on them and also to the pull of guy lines where it is necessary to use this means to prevent their leaning in soft ground.

As indicated in the drawing, heavy nails were driven part way into each pole at and below the ground line. Around the pole and over these nails a circular, wedge-shaped section of concrete was moulded. The nails took up the shear between the pole and the concrete, and the bearing area developed by the latter was made sufficient to prevent settlement.



Concrete Support Easily Placed.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

A STEEL AND CONCRETE FACTORY IN TORONTO, CANADA.

A NEW and up-to-date factory has recently been completed for the National Cash Register Co. of Canada, Ltd., and we are indebted to the journal *Construction* for the following particulars and illustrations.

There are four buildings, arranged in the form of an "L," and they are so designed as to arrange for an extension at a future date.

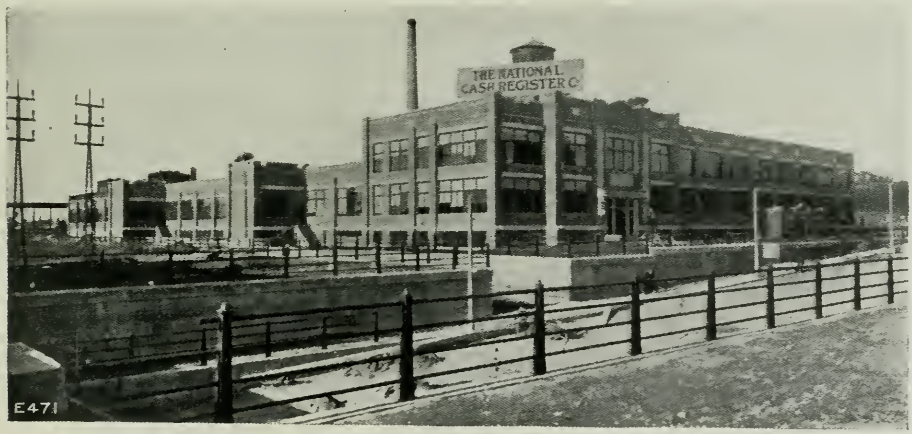


Fig. 1. South and East Elevations.
A STEEL AND CONCRETE FACTORY IN TORONTO, CANADA.

The recent elevation of the railway tracks, and the depression of the street on which the main portion of the building fronts, necessitated the construction of a concrete retaining wall, so that the structure has an imposing appearance on the elevated surrounding ground.

The interior steel columns are encased in concrete. All the floors of the factory are of concrete, whilst brick and steel were used for the outer walls; the foundry floor also is of brick.

The main building has a frontage of 240 ft. by 60 ft. deep, and it is two storeys in height, and has a full-size basement.

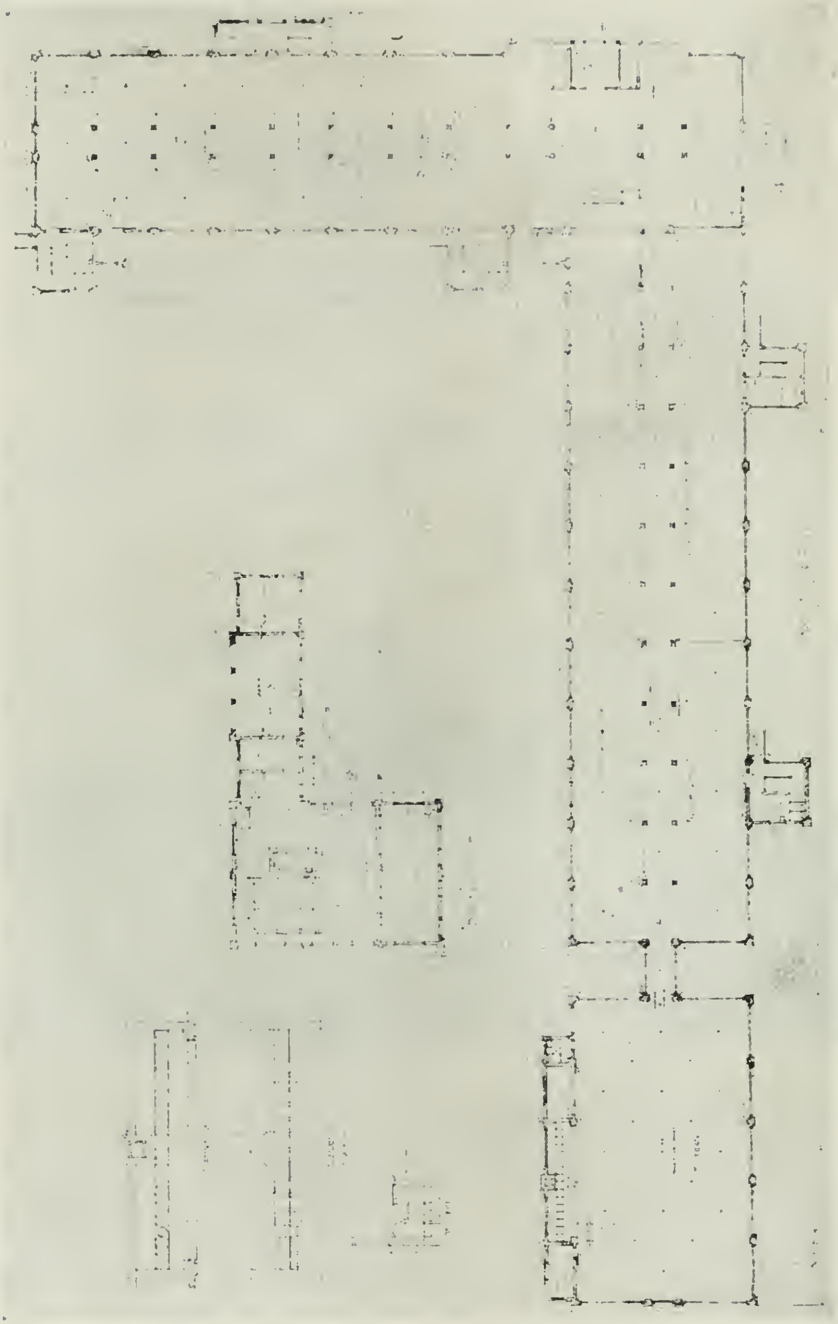
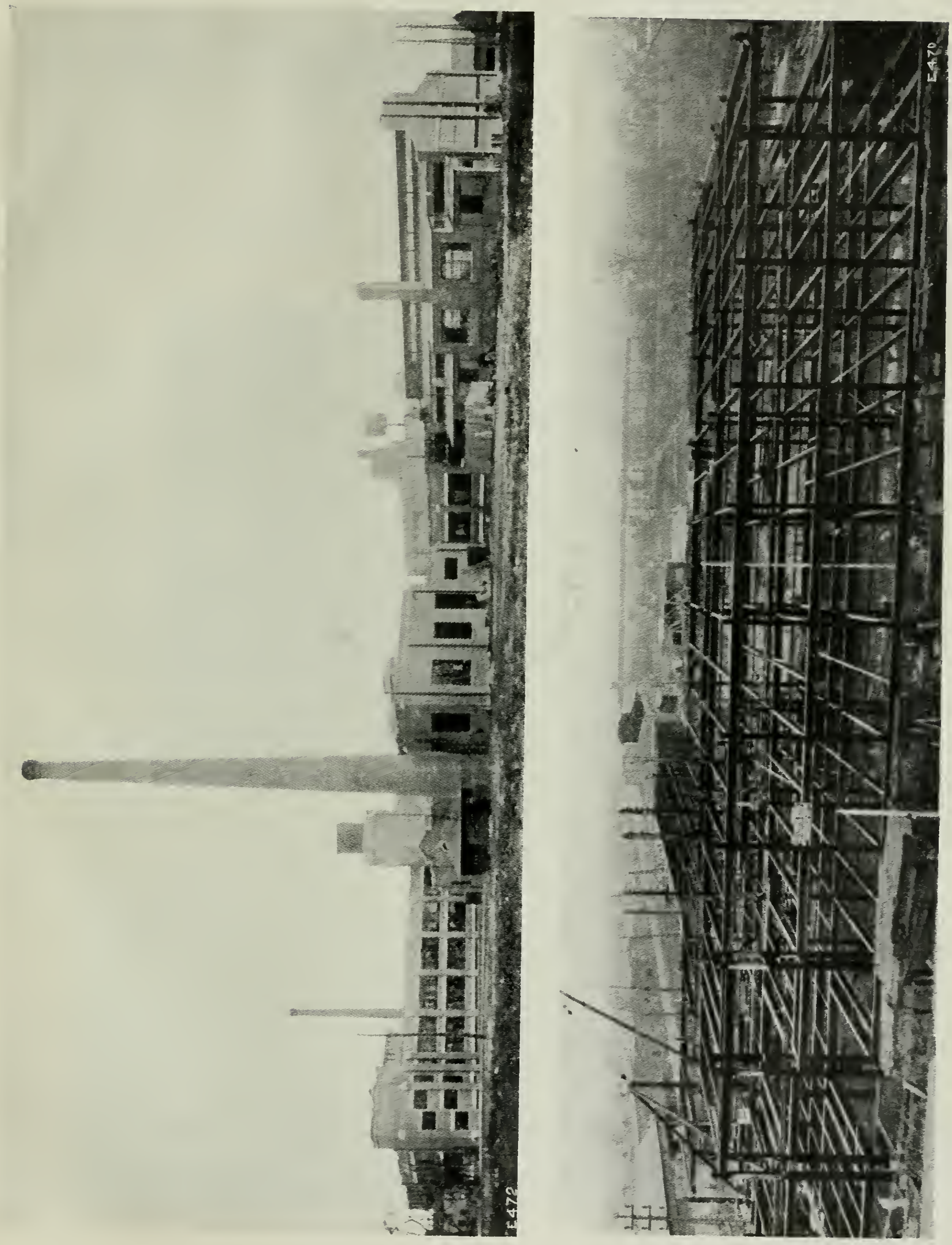


Fig. 2. Ground Floor Plan.
A Steel and Concrete Factory in Toronto, Canada.



Figs. 3 and 4. Rear View of Factory and Steel Frame-work.
A Steel and Concrete Factory in Toronto, Canada.

The frontage of the manufacturing buildings on the south is also 240 ft. by 60 ft., and contains one storey and a basement; while the foundry, connected at the extreme end by an enclosed passage way, is 80 ft. by 60 ft.

There is also a power house, garage, and blacksmith's shop, situated about 60 ft. from the factory buildings, but connected with them by an underground tunnel, this tunnel also serving for the heating mains and live steam lines to the plating and finishing rooms.

As stated above, the factory floors are of concrete and they are laid on " I " steel beams, supported by two columns in the centre placed 10 ft. apart and at intervals of 20 ft. The stairs, lifts, lavatories, and bathrooms are in outside towers.

An employees' recreation room and gymnasium, equipped with apparatus, are also provided.

The architects for this building were Messrs. Page and Warrington, Toronto.

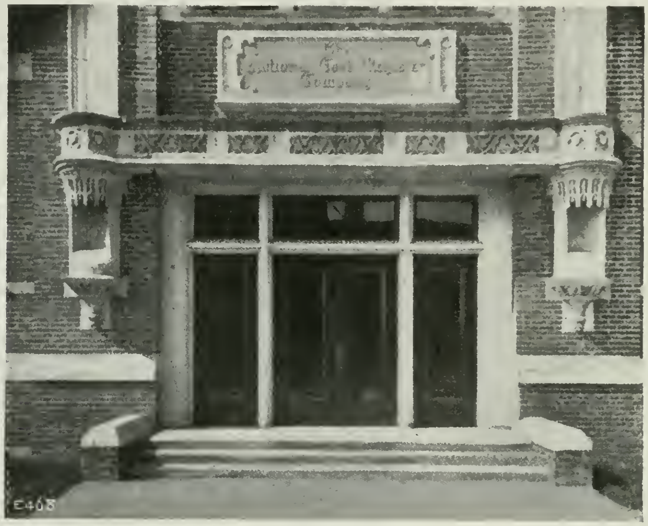


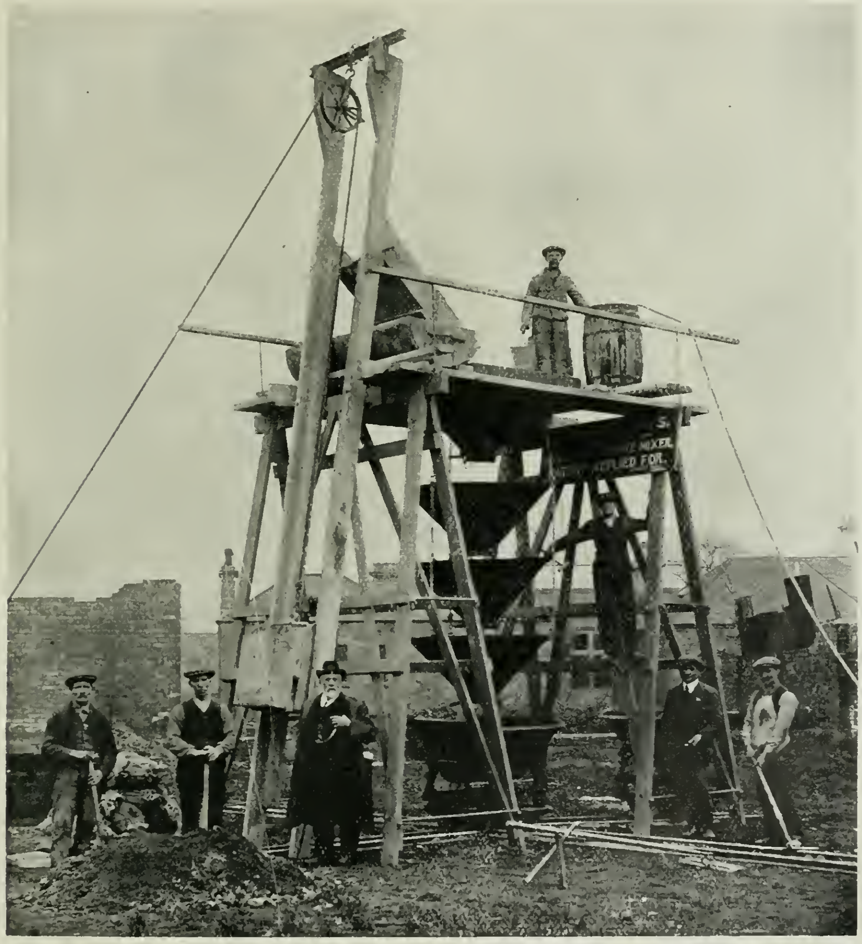
Fig. 5. Main Entrance to Factory.
A Steel and Concrete Factory in Toronto, Canada.

INDUSTRIAL NOTES.

These pages have been reserved for the presentation of articles and notes on proprietary materials or systems of construction put forward by firms interested in their application. With the advent of methods of construction requiring considerable skill in design and supervision, many firms nowadays command the services of specialists whose views merit most careful attention. In these columns such views will often be presented in favour of different specialities. They must be read as ex parte statements—with which this journal is in no way associated, either for or against—but we would commend them to our readers as arguments by parties who are as a rule thoroughly conversant with the particular industry with which they are associated.—ED.

AN IMPROVED CONCRETE MIXER.

In recent years a great development has taken place in the means of mixing concrete, and inventions for the better and cheaper production of concrete have grown in numbers.



Not the least important of these inventions is an improved concrete mixer recently introduced by Messrs. Lawless and Hunt, the well-known contractors of Dundee. The chief novelty and most surprising feature claimed for this mixer is that it is not dependent on any mechanical action for its working, the whole process being performed by the action of gravity.

The mixer consists of a series of inverted cones connected together by chains and disposed one below the other, the whole series being suspended beneath a raised platform. Each cone is provided with a door, which, when opened, allows the contents of one cone to be discharged into the next, and so on through the series, until the material reaches the last cone. A tip wagon or barrow is provided beneath the lowermost cone, which, upon its door being opened, discharges its contents into the vehicle beneath, preparatory to its being transported to the site where the concrete is being laid or used.

To charge the mixer a tip bucket is employed, which is filled with aggregate or cement, as required, at the base, and which is then run up guides by a steam or hand winch. When the bucket reaches the top of the guides it over-balances and discharges its contents down a shoot and into the uppermost cone.

The water constituent may be added in a similar manner or measured from a reservoir on the top of the platform.

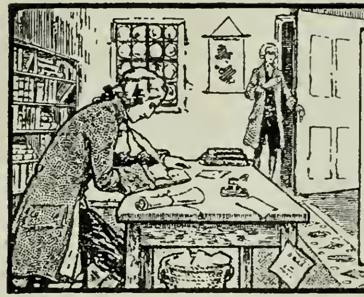
Only one man is required, apart from those working the winch, feeding the device with material, and wheeling away the concrete, to open and close the doors of the cones, all the mixing being performed automatically as the material pours out of one cone into the next. The mixer is erected in a central or other suitable position, and rails laid from the mixer to various points of the work, tip wagons mounted on the rails being used to carry the concrete from the mixer to the various points where the work is in progress.

The quality of the material put out by this machine can be seen in the excellent work done in the floor of the sheds at King George Wharf, Dundee. Messrs. Lawless and Hunt laid a concrete floor there of 6,000 sq. yds., the whole concrete, including granolithic finishing, being made with this machine, and had the approval of the engineer, J. Hannay Thomson, Esq., M.Inst.C.E., M.Sc., etc., and they completed the work to his entire satisfaction.

The present great dearth of labour led to Messrs. Lawless and Hunt introducing the gravity mixer, with the result that they finished the job in the specified time of seven weeks, with one-fourth of the men they would have required had they been working under old methods, and it is stated that the concrete and finishing were put into position in so short a time after being made that it was impossible for the setting of the cement to be disturbed, a vital point in laying down concrete which is not always kept in view.

By extra staffing of this machine, where necessary, a greatly increased output can be got.

Patent rights have been taken out for this mixer.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Concrete in Cottage Building.—In the course of the proceedings of the recent Conference held at Westminster under the auspices of the National Housing and Town Planning Council, several references were made to the necessity for using cheap materials in the building of cottages. Mr. H. L. Paterson, A.R.I.B.A., of Sheffield, in a memorandum discussed some of the newer methods of construction. With regard to *solid or hollow concrete blocks,* he said that these built up as walling stones and sometimes cast with a rough rock face to imitate them cannot be recommended from an æsthetic point of view. If smooth, or if covered with rough-cast, there is not the same objection. *Solid continuous walling in concrete* is filled in between movable boards and the face is afterwards covered with stucco. There are houses standing to-day which were built on this system over forty years ago. *Monolithic concrete walls* are built up by an ingenious method whereby hollow spaces are left in the centre of the wall, tending to keep the house warm and dry. The whole may afterwards be covered with smooth or rough-cast stucco. *Solid concrete walls reinforced* may be made quite satisfactorily about 7 in. thick up to the first floor and 5 in. thick above, but the trouble is that by-laws will not usually allow such thin walls whatever the construction may be. There are several patented systems on the lines stated, and if covered with stucco they appear to be quite as good as brickwork, if not better, for there is a natural affinity between concrete and the stucco covering. *Concrete roofs* are economically formed of concrete reinforced by one of the approved forms of bars. Unless, however, there is a ceiling under the concrete, the rooms immediately below are very susceptible to changes in temperature. In cold weather the moisture in the house condenses on the under side of the concrete and distemper peels off. They are usually nearly flat, but a good method is to form them in a segmental shape with a channel and moulding projecting over the wall faces. It is quite easy to form them in this way and also at the same time to form dormer tops and sides, the whole becoming a monolithic structure without the necessity of lead gutters. It is safer to use asphalt to cover these, or at any rate one of the systems of rendering concrete waterproof.——Professor S. D. Adshead, F.R.I.B.A., who discussed the possibilities of the future village, said the materials of which the solid walls of the cottages were constructed would depend on the possibilities of the district. Where there was plenty of gravel the construction would be of concrete. In a brick district it might be cheapest to build in brick or with a combination of brick and concrete reinforced. Small buildings constructed of almost any material would prove satisfactory if they stood on a good concrete slab. The inner lining of cottages should be constructed of coke breeze concrete slabs, and such slabs manufactured in immense quantities would make cottage building 25 per cent. cheaper.

The Manchester Municipal School of Technology.—The summer evening classes started in the middle of May, and there will be classes during the summer session in the various branches of Mechanical Engineering, Mining, Printing, Photographic Technology, Mathematics, etc. Full syllabus should be obtained from the Secretary of the school.

Class in Reinforced Concrete.—The Principal reported to the Arts and Crafts Committee of Robert Gordon's Technical College that a representation had been made to him for the establishment this session of a class in the subject of Reinforced Concrete; that he had been in communication with persons likely to find the class useful to them; and that, from the replies which had been received, it appeared that about twelve students would attend the class. Subject to its being made self-supporting, the Committee agreed to institute the class, which would be conducted by Mr. Alexander Cruickshank, head of the Building Department of the College. The fee for the course of ten lectures was fixed at £1 1s.

Reinforced Concrete Water Tower.—The General Works Committee of the Town Council of Bacup recommend that plans be approved for a reinforced concrete water tower at Lumb Holes Mill, for Messrs. Mitchell, Ashworth and Stansfield, Ltd.

Miners' Wash and Change Houses.—In the Technical Paper 116 of the U.S.A. Bureau of Mines (reprinted in full in the *Colliery Guardian*), Mr. Joseph H. White deals at some length with these structures. He points out that large and small mining companies are providing buildings where the miners can remove their soiled working clothing, bathe and change into clean clothes before returning home. These buildings can be erected at a comparatively small cost.

Building Material.—The building should be designed primarily to ensure cleanliness and convenience rather than to be ornamental. Sanitary round corners should, if possible, be introduced at all intersections. The amount of wood in the construction of the building should be reduced to a minimum because it is inflammable, will harbour vermin, and is difficult to keep clean. Brick, stone, poured concrete, concrete blocks, and hollow tile are materials best adapted for the building.

Inexpensive Construction.—If it is necessary to reduce the cost, a wood-framed building covered with galvanised corrugated iron may be erected. The exterior of the roof and sides of such a building may be covered with galvanised corrugated sheets. The under side of the roof and the inside walls, from the eaves down to the bottom of the windows, may be lined with asbestos-cement sheets, asbestos metal, or similar fire-retarding material. The inside walls, from the floor up to the bottom of the windows, may be lined with No. 16 gauge black (flat ungalvanised) sheets. The floor should be made of concrete. Such construction would make an inexpensive, reasonably sanitary, fire-retarding building.*

Concrete and Brick Construction.—A combination of concrete and brick may be used to advantage. The floor and walls to a height of 7 or 8 ft. may be made of poured concrete, and the remainder of the walls may be made of brick.

The superstructure resting on top of the concrete walls may be made of cheaper material than brick if it is necessary to economise. The point to be emphasised is this—the floor and the lower part of the walls receive the worst wear and tear, and are in most danger of fire from within, and will be most abused and dirtied. Concrete stands up well under such abuse; a hose may be turned upon it, and it can be scrubbed without much difficulty. Sharp corners, offsets, crevices, cracks, ledges, and similar vermin and dirt catchers, can be easily avoided with poured concrete. The lower concrete wall can be simply poured, because the window openings can be placed in the brick walls above.

Care should be exercised in finishing the concrete floor. The concrete should be made rich, say, 1 part cement, 2 parts sand, 3 parts stone, mixed wet, and brought to a smooth finish. The floor should have a decided pitch, so that when it is scrubbed the water will drain off readily. This simple provision will save much of the attendant's time. The pitch should be about $\frac{1}{4}$ in. to 1 ft., and numerous outlet drains should be provided.

Certain paints and mixtures to be added to the concrete have been recommended for making the concrete surface smooth and durable. When the cement to be painted is freshly laid, before being painted it should be treated with a lime neutralised primer. The most efficient primer for this purpose is a solution of zinc-sulphate crystals dissolved in water in the proportion of 4 lb. to 1 gal., applied with a wide brush to the surface of the cement, and allowed to dry. Then a heavy coat of prepared oil paint, made with zinc and lead, should be brushed well into the surface of the cement. There should then be applied a surface coat of special gloss floor paint.

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* A similar type of building was recommended by the Departmental Committee appointed by the Home Secretary to consider the provision of such accommodation in British Mines.

The walls of the building should be high, perhaps 16 or 18 ft., particularly if the clothes of the miners are to be suspended from the ceiling. The bottom of the windows should be about 6 or 8 ft. above the floor for the sake of privacy, and also that the windows may be opened without causing a direct draught on the men. The windows should be ample in area, so that the building will be well lighted and well ventilated, and should be so arranged that they may be opened and closed easily. It is preferable to have them hinged like a transom, instead of sliding up and down, as that arrangement permits the full area of the opening to be utilised for ventilating purposes.

The type of roof is important, because the roof is a part of the ventilating and drying system. In some instances, a monitor is built along the full length of the ridge, with windows that may be operated from the floor by a geared device. Instead of the monitor roof, a gable roof is sometimes built, in which rotary ventilators are installed to draw the air out of the building. If a sufficient number is installed, the rotary ventilators are perhaps more efficient air removers than monitors, because advantage may be taken of shifting winds.

The Kaponga Town Lighting Scheme, New Zealand.—The installation of the hydro-electric plant by the Town Board of Kaponga, Hawera County, in the North Island of New Zealand, will be completed this month. The township is situated on the Kaupokonui stream, across which a concrete dam was built to supply the necessary power. Concrete has been largely used throughout, the power-house, surge tank, reticulation pipes and transmission poles having been made of this material.

The plant consists of a single discharge horizontal shaft type Boving turbine capable of developing 70 b.h.p. under a working head of 33 ft., coupled to a 45 kw. G.E. dynamo, 230-5 volts direct current. The switchboard has the following instruments: One ammeter 0 to 250, one voltmeter, one d.p. knife switch, one current breaker, one rheostat, one chart reading wattmeter, one resetting lightning arrester, and a D.P. secondary battery of about 128 cells with a capacity of 90 amps. has been installed. There are about two miles of pole line. The system is two wire, with the street lighting on a separate circuit. The National Electrical Engineering Co. were the contractors for the plant. Mr. Horace Priestley is the engineer-in-charge.

Cement for Ecuador.—According to the British Consul about three-fifths of the cement imported into Ecuador used to come from Germany. The demand is increasing on account of the sanitation work which is in progress in Guayaquil, and also on account of the new Municipal Building Ordinance, which requires the foundations of all new buildings to be constructed of concrete. It is satisfactory to note that the superior quality of barrels used by United Kingdom exporters greatly reduces the percentage of loss in transit. On shipments of cement from other countries the percentage of loss, through employing weak and inferior barrels, often reaches as much as 40 per cent.

Concrete Pavement.—A six-mile stretch of concrete pavement, 15 ft. wide and 4½ in. in depth has recently been completed by the California Highway Commission in Santa Barbara County, between Santa Maria and Orcutt.

Dam in Quebec.—According to information received from the Minister of the Interior at Ottawa, the contractors for the Quebec Government are preparing to proceed with the construction of a dam on the St. Maurice River, in Quebec Province. The dam will create a reservoir of approximately 300 square miles.

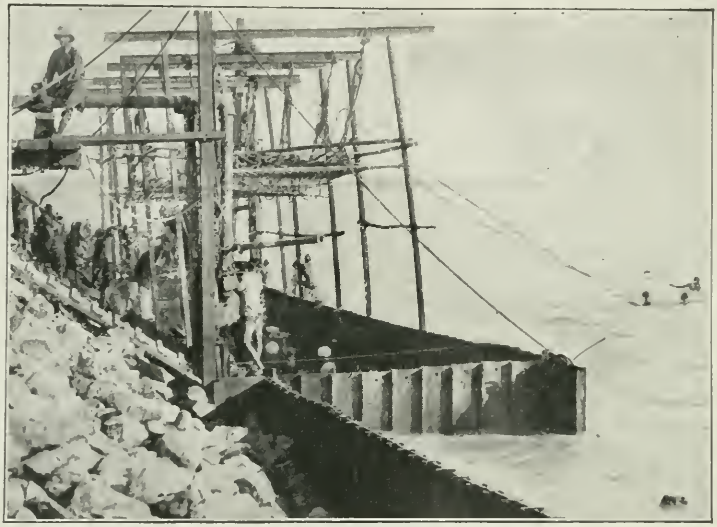
Bridge at Sydney.—A Bill is in course of preparation by the New South Wales Government providing for the construction of a bridge connecting the City of Sydney with the Harbour, at an estimated cost of £3,000,000.

New Dock at Boston.—A contract has been signed for the construction of a dry dock at Boston, to be built by the State. It will be the largest in the United States. The dock will be founded on a ledge, and 125,000 cu. yds. of concrete, taking about a barrel of concrete to the yard, will be laid.

Reinforced Concrete Chimney.—A chimney on the Monnoyer system of reinforced concrete has recently been constructed at Quebec. The following are a few short particulars of the work carried out, taken from the *Canadian Engineer*:—

The chimney constructed at Quebec for the locomotive shop plant of the National Transcontinental Railway is 200 ft. in height above the ground level. The inside diameter at the summit is 9 ft., and at the base 14 ft. The foundations were carried

The BRITISH STEEL PILING Co



Cofferdam for foundations of Sea Wall for Back Bay Reclamation at Bombay, India. The grillage seen suspended over the cofferdam is ready for lowering into the excavation, when it will be embedded in concrete. Withdrawing of the piling behind and redriving ahead went on continuously.
"Universal Joist" Piling and Pile Driving and Withdrawing Plant all supplied by our agents, Messrs. Richardson & Cruddas, Bombay.
The piling was driven with our No. 7 size McKiernan-Terry Patent Hammer.

Weights of Piling :—

"SIMPLEX," from 22 lbs. per sq. ft. assembled.

"UNIVERSAL JOIST," from 43 lbs. per sq. ft. assembled.

Large Stocks of Piling and Plant available for Sale or Hire.

DOCK HOUSE, Billiter Street, LONDON, E.C.

down to solid rock, which was encountered 19 ft. below the surface. The smoke flue, which opens into the chimney below the ground level, is 11 ft. 5 in. high by 5 ft. 6 in. wide inside, and is constructed of reinforced concrete.

The vertical reinforcing rods in the foundations were carried into the footing almost to the base, and continued to the top of the foundation, overlapping and bonding those of the superstructure for a length of from 4 to 5 ft.

In constructing the foundation the footing was first poured for a depth of 1 ft., then the vertical rods were set and held in place by means of wood framing. After these rods were placed the balance of the footing, about 3 ft., was poured, and allowed to set. The framing was then removed from the rods, and the forms for the balance of the foundation constructed. The concrete in the footings was poured by means of a derrick and a bottom-dumping bucket; but for the upper portion it was found more convenient to use barrows, owing to the limited space between the forms, and the quantity of steel which had to be held in place during the work. Before reaching the top of the foundation the reinforcing rods for the superstructure were placed and the concrete poured around them. The concrete was then allowed to set and the forms removed before commencing to lay the blocks.

In the meantime the making of the blocks was proceeding in an adjoining shed, so that by the time the foundation was completed there were sufficient blocks on hand to keep the erection going continuously.

The blocks were made in four collapsible forms, these being so constructed that they served equally for all blocks from 4 in. to 9 in. in thickness, and any length desired. The concrete was mixed in a small gasoline-driven mixer. The concrete, which consisted of a 1 : 2 : 4 mixture, was placed in the forms in a semi-dry state, the reinforcing rods inserted, and the whole well tamped. Immediately upon the completion of a block it was removed from the form and placed to one side, to be sprinkled daily for a period of about two weeks or until ready for laying. It is perhaps needless to state that the forms were well cleaned and soaped after each operation.

In the erection the blocks were at first hoisted into place by means of a steam-driven derrick, and the mortar hauled up in buckets with a rope. When the chimney had attained too great a height for the derrick a hoist was installed on a platform in the interior, and a gasoline engine placed at the end of the smoke tunnel in the power-house. By this method the blocks and mortar were hoisted up inside the chimney, and the construction continued thus until the finish.

For the mortar forming the bonds between the blocks a mixture of one of cement to two of sand was used. The chimney was lined inside with 4 in. of firebrick set in fireclay, to a height of 50 ft. above the top of the smoke flue. A sectional steel ladder was built up along with the erection of the chimney, the supports being tied into the vertical reinforcing rods. The whole was surmounted with a cast iron cap.

Concrete Pontoons.—Four concrete pontoons for landings for small boats at Balboa are being built on the floor of the new dry dock. They will support gangways on the heads of the slips alongside one of the piers. Each will be 120 ft. long, 28 ft. wide, and 8 ft. deep; and, as the pontoons are designed to support heavy weights and withstand severe knocking, the system of reinforcement is elaborate.

The Unreliability of Dry Powder Extinguishers for Air Raid Fire Dangers.—Although somewhat outside our general scope, so many of our readers are interested in questions relating to air raid dangers that we are desirous of referring to the Report received from the Home Office* dealing with certain questions relating to the extinction of fires arising from air raid bombs. It appears that a valuable series of experiments have recently been made by a Home Office Committee, presided over by Major A. McN. C. Cooper-Key, C.B. (of the Explosives Department), and this Report shows, in the clearest possible manner, that the use of dry powder extinguishers should be avoided, and that the public should pin their faith in water. To quote the Committee's Report, it says :—

> " In conclusion, the Committee are confident that by far the best extinguishing agent is a plentiful supply of water applied in the manner most

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* Report of the Committee appointed by the Right Honourable the Secretary of State for the Home Department to conduct experiments to test the value of Dry Powder Extinguishers as compared with water and other " First Aid " appliances for extinguishing or effectively controlling fires such as are likely to be caused by bombs. (Cd. 8250.) Price 1d.

convenient, and that the use of dry powder extinguishers is to be deprecated as not only giving a misleading sense of security, but being practically useless for extinguishing or effectively controlling fires likely to be caused by bombs."

To those of our readers who are interested in chemical industries, a footnote in Appendix III. makes amusing reading, for the investigation at the National Physical Laboratory has shown powder extinguishers generally to comprise from 46 to 56 per cent. of bicarbonate of soda, a constituent purchaseable at about 4s. 6d. per cwt., or almost exactly ½d. per lb. Thus the value of the bicarbonate of soda in a powder fire extinguisher of usual size does not exceed in value 1½d., whilst, if our recollection serves us rightly, the prices charged for these appliances vary anything from 3s. to 7s. each, and the Committee rightly describe these prices as "extortionate."

PUBLICATIONS RECEIVED.

Road Reinforcement.—The British Reinforced Concrete Engineering Co., Ltd., have just issued another of their interesting booklets on this important subject. At the present moment, especially when many of our country roads are being subjected to heavy motor traffic, and the question of repair and re-making of roads arises, the matter is one claiming special attention.

The booklet contains many interesting illustrations. Among them is one showing the construction of the concrete foundation of the City Quay at Dublin, reinforced with B.R.C. fabric. Another illustration shows a sea wall at Falmouth, also reinforced with this material. For full particulars apply to the British Reinforced Concrete Engineering Co., Ltd., 1, Dickinson Street, Manchester.

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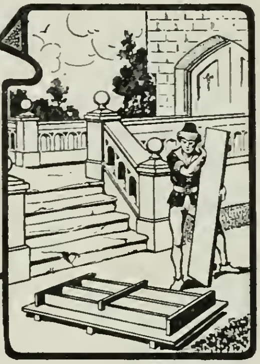


THE ADAPTABILITY OF LOCAL MATERIALS AND THEIR APPLICATION FOR GENERAL PURPOSES.

By THOMAS POTTER.

In this supplement we present some notes as to suitable aggregates for concrete obtainable from local materials, together with particulars as to the construction of walls, footpaths, the use of concrete on the farmstead, etc.—ED.

INTRODUCTION.

THERE is more scope for the use of concrete in various ways in agricultural and rural districts than there is in towns, and of a different description. Much of it is of a simple character and requires but little scientific knowledge. The principal material—the aggregate—is obtainable at times close at hand and, if otherwise, usually within a reasonable distance and at a small cost. The matrix—Portland cement—should be of the best quality, no matter what the purpose of the concrete; if otherwise, and cheapness is the factor aimed at, failure is the usual result. Appearance is no criterion of its quality, but if obtained from reputable manufacturers or their agents, is guaranteed to be according to British standard specification and has the manufacturer's name or brand on the sacks, its quality may be relied on.

THE AGGREGATES.

Pit Gravel is available in many neighbourhoods, but is frequently mixed with clayey or argillaceous matter, which makes it suitable for garden paths, but not for concrete, unless it is eliminated by washing, a troublesome process. Its suitability can be ascertained by squeezing some in the hand, and if it retains its shape it is owing to its clayey particles, or by stirring some in a pail of water, quite a rough and ready method in common use. If the latter is discoloured to any extent it is unsuitable unless washed again and again.

Brick and Pottery Refuse is a good aggregate if broken to a suitable size, the latter depending upon the purpose it is for, but none larger than would pass a $1\frac{3}{4}$-in. mesh, the smaller the bulk of concrete the finer should be the aggregate. It should not be of uniform size, but graded to that of coarse sand, that the concrete may be homogeneous, or dense throughout. Some experience soon determines this. Breaking with a hand hammer does not give good grading results; nothing is better than a Blake crusher operated by steam power. If the materials are clean, washing is not absolutely necessary, but all materials that have passed through fire or through a crusher are coated with impalpable dust, which it is desirable to eliminate. This is easily performed when mixing the concrete on a movable wooden platform, by sloping the latter slightly to enable the washings to run away, not enough to carry therewith the sand-size portions of the aggregate. The washing should be performed by adding water to the measured heap on the board, while two men, one on each side, turn it over with shovels, while another rakes it about with a long-handled two-pronged rake. If the water is directed to a sump hole, and water has passed away, a thick pasty mass is the result.

Field Flints and Chalk Flints picked from the surface of agricultural land or found embedded in chalk make excellent concrete if crushed, and require no admixture of sand or other ingredients if the crusher is set to the necessary size, but cannot be broken by hand to produce proper grading, and should be washed as previously described.

Brick and Stone Débris from buildings in process of demolition come under the same description as brick-yard débris, except that old mortar should be got rid of as far as practicable. If the concrete is to be used for walls that have to be plastered, chimney bricks should be avoided, the soot hanging thereto penetrates and discolours both lime and cement mortar, and this cannot be remedied.

Stone Quarry Refuse should be passed through a crusher; it is too flaky in character otherwise. Most quarries possess crushers for the purpose. It should be washed as described for brick-yard débris.

River Gravel obtainable from the beds of rivers and their tributaries is usually a good aggregate if clean, but this is not always the case, it is often mixed with mud arising from the soil which is washed in from the banks on either side, but which depends largely on whether it is a quick-running stream or the reverse. The mud is easily removed by washing on the mixing platform, as described previously. If it contains too large a proportion of the sandy element, the latter should be screened out and used for lime or cement mortar. Too much sand—no matter the kind—weakens the concrete.

Ashes or Cinders from boiler furnaces make good concrete, but require grading, and should be free from other substances, such as cotton-waste, soot from boiler tubes, etc. They may contain fine coal particles, but experiments made in the United States proved that these were not injurious if not more than 5 per cent. was in evidence. Some electric lighting and gas works crush and screen the cinders suitable for concrete purposes.

Chalk will make fairly good concrete, more especially if obtained from below the upper strata. It should be graded and the fine portion screened out, coarse sand being added to take its place. It is advisable to allow the chalk to aerate for a time to part with the latent moisture which it contains. Tests have proved that chalk concrete is frost-proof under severe conditions, and walls of buildings erected with it many years since are free from internal damp. Per contra, chalk is not recommended if only the top strata is available, although it has been used for many buildings erected years since with a fair amount of success.

Ashes from locomotives are usualy clean and well adapted for concrete purposes, and most railway companies supply them delivered at any of their stations at a nominal charge, but care should be taken that they do not come from a line where lias limestone abounds. Some railway companies allow their drivers to utilise fragments in the boiler furnaces to economise coal, with a view of obtaining the gratuity which is granted them for low consumption. These fragments when mixed with the ashes are converted into lime, and not distinguishable. Being slow slaking, the latter may not occur until after the concrete has been in place for some time, when irreparable rupture takes place. This applies to the L. and S.W. and some portions of the Midland lines, and possibly to others.

Coke Breeze was at one time a favourite concrete material, and was given away by gas companies; this is not, however, the case now. Being of a somewhat soft nature, it has been assumed that concrete made therefrom would crush under a heavy load, but Mr. Kirkaldy's tests proved that, while stock brickwork in blue lias lime mortar crushed at 46½ tons per sq. ft. when 2½ years old, coke breeze concrete made with 6 parts of breeze and 1 part of cement crushed with 131 tons per ft. when the same age.

Coal Residues of all descriptions have been condemned by reason of the sulphur they contain, but, if washed, this is considerably eliminated, and aeration helps, too, in this direction. The writer has used both cinders and coke breeze, mostly unwashed, in considerable quantities for many years without a failure, and Sir Henry Tanner once said that he had used coke breeze for new Post Office floors for a long time and had heard of no failure. Where it has arisen it has been possibly through the description of the material used. Breeze is a term applied to many substances—domestic ashbin refuse, for instance—for burning clamp bricks, and which has been known to be supplied for concrete purposes under a misapprehension.

Slag from Iron Ore is a material that makes good concrete, but contains a good deal of sulphur, which is very apparent when being passed through a crusher. The immense mounds of slag in the neighbourhood of iron mines, and which have been there for many years and aerated during that time, are safe enough for concrete purposes, more especially if rinsed with water on the mixing platform. At many iron mines slag is crushed and screened to adapt it for concrete purposes and supplied at a cheap rate. All the materials named will withstand climatic changes without any injury, and freezing will not affect concrete made therewith.

PROPORTIONING THE INGREDIENTS.

For proportioning the ingredients the rudimentary method of depositing a certain number of barrow-loads of the aggregate on a mixing board and adding thereto a sack of cement is too rough and ready a system. As the strength of a chain depends on its weakest link, so does the necessity of concrete being equably and consistently alike throughout, no matter its purpose. The only safe method is to have a measuring box without a bottom holding the exact amount of aggregate required. This to be determined by the proportion of cement; if the latter is supplied in two-bushel sacks and the proportion is to be 1 of cement to 7 of the aggregate, then the box should hold 14 bushels and be placed at one end of the platform and filled with the aggregate, and the latter straightened with a straight-edge. The cement is then shot on top of the aggregate and the box lifted up by the handles.

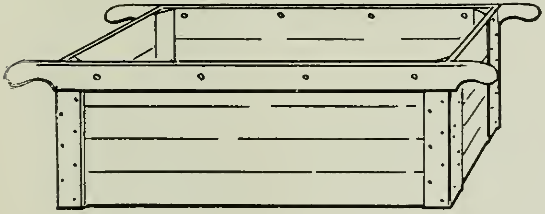


Fig. 1.

The materials should then be turned over at least twice by two men, while a third rakes it about with a two-prong long-handle rake. It is not sufficient to deposit it in the same position as lifted by the shovels, but the latter turned over to more thoroughly intermix it. The process should then be repeated not less than twice while water is being added by a fourth man, preferably by means of a large water-pot with a coarse rose attached. The amount of water required varies with the nature of the aggregate: it may be dry or the reverse, and the materials may be absorbent or otherwise, but if the mixing platform is slightly sloping and water does not run away from the heap, and the latter is in a semi-squashy condition, it may be considered as suitable.

WALLS.

In rural and agricultural districts concrete walls might in many cases take the place of wood fencing or brick. If the cost is somewhat more than wood, upkeep is avoided. For boundary, enclosure, and garden walls 4 to 6 ft. in height, 4 to 6 in. in thickness is ample, but if the length is considerable, piers at intervals can be adopted. The proportion of cement to aggregate should be about 1 to 8. It is advisable to insert in the walls when in progress three or four lines of ¼-in. iron rods or old fencing wire, iron hoop, or anything of a similar character, the uppermost line being near the top and the others spaced 6 to 12 in. apart, the spacing apart increasing the nearer they approach the bottom. The object of these is to resist temperature changes, which cause the cracks that so often disfigure concrete walls.

The forms or shuttering to form a trough into which the concrete is to be deposited consist of posts of any size, but usually 4 by 3 in. to 7 by 2½ in., whichever is most convenient, and any distance apart, but preferably about 10 ft. These must be connected together in pairs by small bolts, wood cleats, or iron hoop ties, and fixed in position by means of struts and ties. Boards, usually an inch thick, are nailed to the inside faces of the posts and strengthened by ledge-pieces externally. But as the boards cannot be liberated until the wall is finished, it is more economical to screw wood fillets to the posts, cutting the boards to fit in easily between the posts and bearing against the fillets. No nails are then required. When the concrete has hardened sufficiently, usually one or two days, the wood fillets are unscrewed and fixed higher up for the next lift of concrete. The ledge-pieces on the boards are connected together by a small bolt and nut passing through the bottom board and an inch from the bottom edge. When the form boards are raised for the next lift of concrete these bolts bearing on the finished concrete keep them in place, and the bottom board covers the finished concrete an inch. For inch boards the ledge-pieces should not be more than 4 or 4½ ft. apart and measure about 3½ by 1¼ in., and

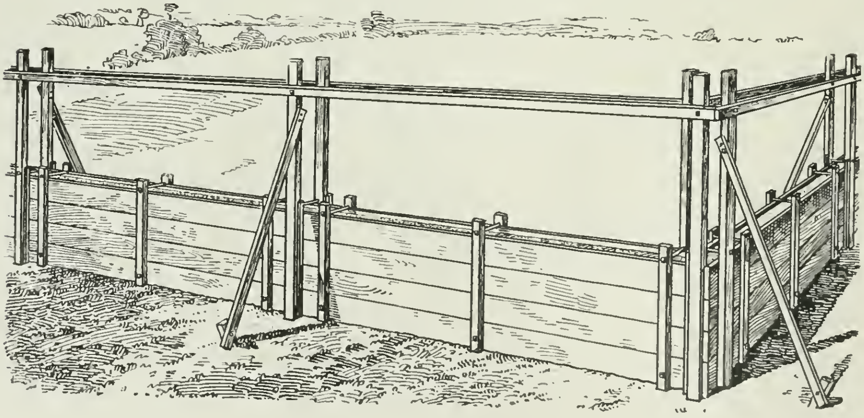


Fig. 2.

nailed only to the bottom board. The connecting bolts can very readily be punched out and the holes filled in with cement driven in solid. The forms or shuttering usually consist of four 7 by 1 in. boards; common flooring is usually employed, or what is known as country-cut stuff, but which is now difficult to obtain owing to the war. With a very little practice any village carpenter and village labourers are able to perform this work. If a smooth surface to the concrete is required, cement and sand mortar 1 to 4 can be applied with a steel trowel as thin as possible, and trowelled off to the surface of the concrete with a wood hand-float and a liberal amount of water with a fibre distemper brush, and at a small cost.

COPING.

For coping walls of this character there is nothing simpler and cheaper than forming it *in situ* of a semi-circular section. Wood templates, ½ in. thick or less, fixed about 10 ft. apart with cement, and straightening the concrete from template to template with a long wooden straight-edge, is all that is required; but the concrete should be of a finer description and finished with a wooden hand-float. Projecting copings are unnecessary, as there are no mortar joints to be washed out, as with brick walls, and unless high enough to be out of the reach of cattle and passing vehicles are liable to damage; the most severe frost has no effect on the concrete copings.

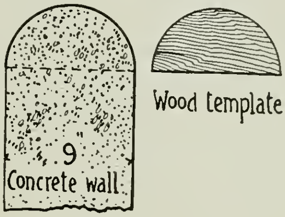


Fig. 3.

Any of the aggregates previously named, except chalk, are suitable for walls of this description, and if ashes or soft brick débris is used nails can be driven therein for training flowers, etc.

COTTAGE WALLS.

The same system of forms applies to walls of buildings, but it is self-evident that for two-storey and higher buildings their cost would be considerably more than that of low walls and one-storey buildings. Under any circumstances, forms are an important item in the cost, but if they can be re-used again and again it is very much lessened.. If otherwise, as, for instance, for a pair of cottages, concrete walls would amount in many cases to more than brick. Walls constructed with solid blocks or cast slabs is another method of construction, but unless a considerable number are required and suitable materials are readily available, they are not so economical as if built with forms. A mason or bricklayer is required to fix them, and they are not usually so rain and damp proof. If only a limited number are required it is better to buy them from specialists who make their manufacture a business.

The materials for making slabs should consist of clean, fine materials, none larger than would pass a ¼-in. mesh and graded to coarse sand size. Slab walls should be built hollow, the slabs 2½ or 3 in. in thickness, with a space between, to form hollow construction, and bonded together with metal ties; and although this answers for buildings not exceeding two storeys high, they are not suitable for farm buildings subject to rough use.

GARDEN PATHS.

Garden paths may be formed of concrete by means of wood strips 3 by 2 in. or 3 by 1½ in., fixed in each side to stumps driven in the ground and acting as screeds for the concrete. Strips of wood, ¼ in. to ½ in. thick, with the top edges curved as desired, should be fixed transversely to the side strips and about 8 ft. apart, and also used as screeds. Their object is to prevent cracks which would otherwise arise at intervals from temperature changes. They can be left in the concrete, and when they eventually decay it is of no consequence. The concrete should be 2 to 3 in. thick and finished as described for walls, which prevents slipperiness. A depth of 3 or 4 in. of dry ashes or rough core below the concrete is advisable, and any of the aggregates described—except chalk—are suitable and durable; 1 part of cement to 6 parts of the aggregate is a suitable mixture.

PUBLIC PATHWAYS.

For pathways where there is a considerable amount of traffic, crushed granite or other hard material is preferable, and treated as for garden paths, but mixed in the proportion of 1 of cement to 3 or 4 of granite. The latter should be washed and graded from $\frac{3}{8}$ in. mesh down to sand size. Most quarries utilise stone chippings by crushing and washing them suitable for paving purposes. Slag, if aerated, is as good as granite and as durable, and can be had prepared ready for use at many places. Fine gravel or shingle makes good paving if prepared as described, but as the wear is imperceptible while the cement and sand wear away to some extent in course of time surface roughness is the result, but is not objectionable for village streets, for instance, as it prevents slipperiness arising from their oft-time muddy condition.

FARMSTEADS.

There is no class of building where concrete can be more advantageously employed than farmsteads. The buildings are mostly one storey high, the plans devoid of many irregularities, the windows and doors less in number than in cottages or farmhouses, and the nature of the work, strength and durability excepted, of less importance than inhabited buildings. The walls scarcely ever require to be more than 9 in. thick and less is often sufficient.

Floors.—Owing to the rat plague, every building, no matter its purpose, should have concrete floors or paving. There is scarcely any other material that rats will not eventually find a way through, and instances have occurred where the ground floors of old farmsteads infested by rats, having been removed and replaced by a rubble bottoming and concrete, the rats have migrated in a body to more congenial quarters.

For cart-horse stables hard blue Staffordshire bricks should be laid on the concrete, but for all or most other parts of buildings the concrete itself provides a sufficiently good surface. It should be made in the proportion of 1-6, carefully straightened, well beat with a grass beater having sheet-iron fixed on the face, and grouted with neat cement well worked in with a new birch or stable broom. Quarry stone, hard brick-yard debris and slag are suitable aggregates; boiler ashes will do if those named are not readily available, and floors made therewith have stood the wear and tear of many years' use with little appreciable injury. Where the cost is not an important consideration a smoother surface can be obtained by applying a coat of cement and granite chips 1-3, three-quarters of an inch in thickness, trowelled off to a smooth surface—granaries and corn stores, for instance, where the corn is kept loose in bulk. But for all paving and similar purposes much less water should be used in mixing the concrete, sufficient only to moisten the particles, as the effect of impact from the use of the beater is to cause effluence of water to the surface, and with it some portion of the cement, and which is the cause of slipperiness.

Drinking troughs are easily constructed of concrete by means of temporary wood forms, the sides and ends being ledged together and kept in position by light wood clamps. The concrete may be about 2 in. in thickness at the top and 4 in. at the bottom, and the troughs made *in situ*. The bottom may be any thickness the nature of the ground renders necessary to prevent subsidence, and when the forms are removed the concrete externally and internally cemented with a thin coat of neat

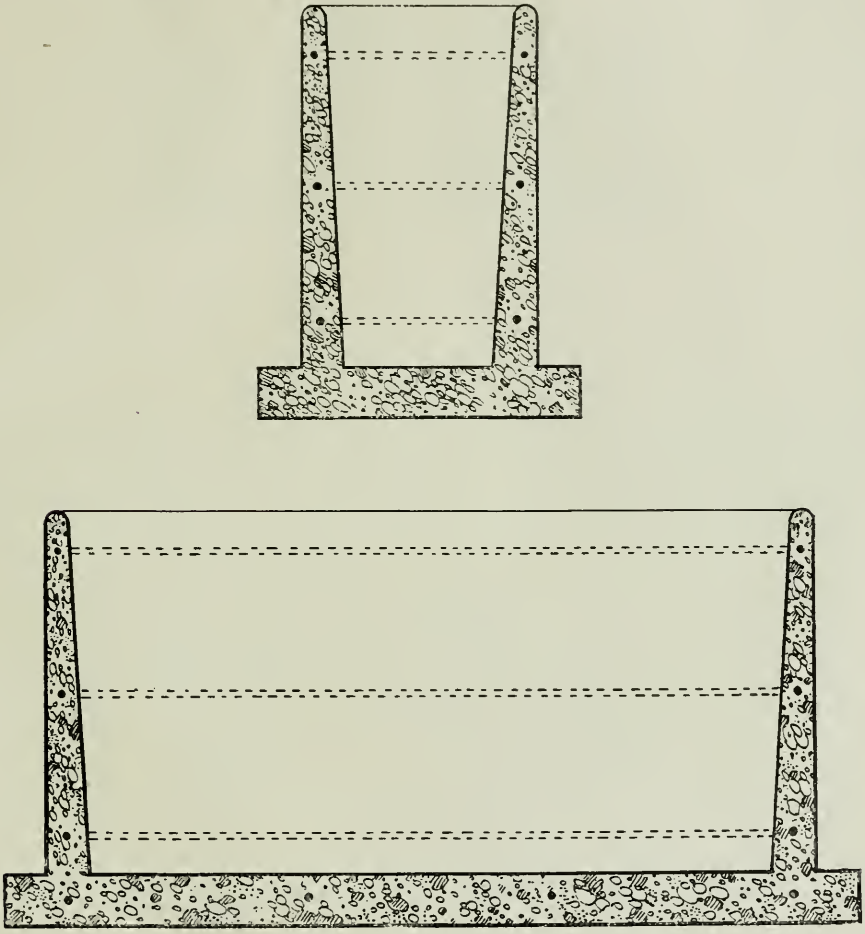


Fig. 4.

cement. A few quarter-inch rods embedded in the concrete, more especially in the bottom, is advisable. Portable troughs that require moving from place to place can be made lighter to reduce the weight.

Cattle mangers are superior in every way to wood. The foundation having been put in, the form boards, ledged together, are fixed rigidly to the line of front, and the concrete deposited therein, the curved portion shaped with a trowel, and a wood form E placed in position and weighted to keep it in place, and form the trough in which the concrete is placed, and gently punned or pressed to render it dense. Mangers of this description are sometimes required in long unbroken lengths, which enables the forms to be 8 ft. to 10 ft. long, and when one length of the manger is complete the same form can be removed and re-fixed for another length.

C.C. are reinforcing rods. The concrete for all work of this character should be a somewhat better quality than for walls and pavings, usually 1-4, and the aggregate none larger than would pass a three-quarter inch mesh for the portions more liable to stress.

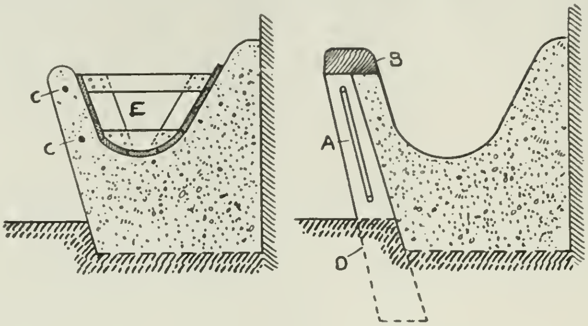


Fig 5.

Slides for ties or ropes may be formed with posts D, about 4 by 3 in., and iron rod guides (A) attached thereto by driving them in the sides of the posts, to admit an iron ring to work freely up and down. A cap rail of hard wood (B) with rounded corners is usually fixed to the posts. Pig-troughs can be formed in a similar way or cast in a wood mould, as preferred. Piggery walls are usually about 4 ft. in height, and a wood food shoot fixed therein. A more durable and more convenient shoot is formed of concrete, easily cast in a wood mould. A A are reinforcing rods; C the end of the shoot on which the bucket rests at D. Any carpenter can readily make the mould or form for casting this kind of shoot, and one mould is sufficient for any number.

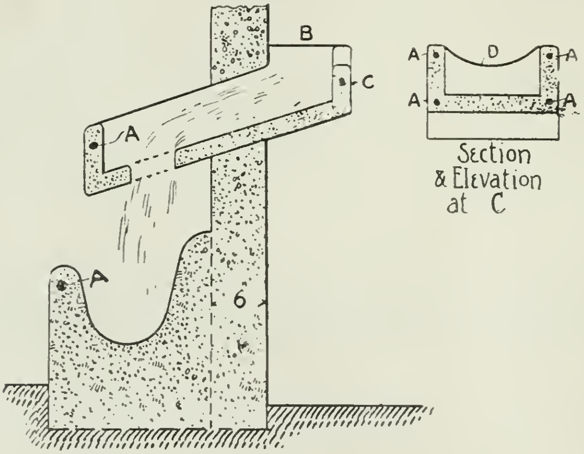
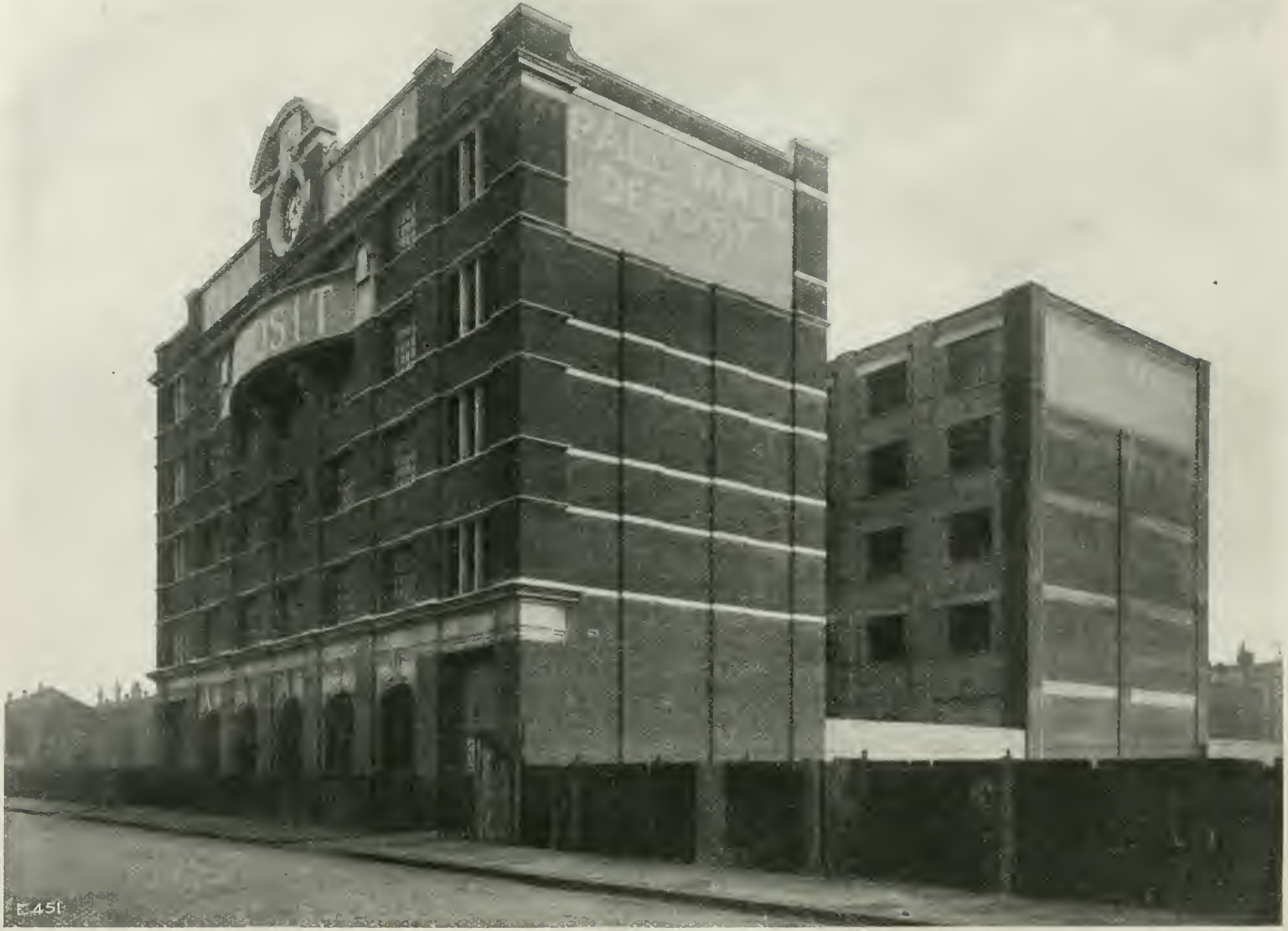


Fig. 6.

This article will be concluded in our next issue, when we shall also include some further illustrations.



Front Elevation.

New Building for the Pall Mall Deposit and Forwarding Co., at Barlby Road, Kensington.

(See page 315.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XI. No. 7. LONDON, JULY, 1916.

EDITORIAL NOTES.

THE NECESSITY OF CO-OPERATION.

THERE has never been a period in our history that equals the present time for the need of co-operation amongst all classes of workers and employers, and amongst the different members of any particular section of the community. By working in harmony and under proper organisation the maximum effect is produced in the minimum time, and to bring the existing condition of affairs to a speedy and successful conclusion it is necessary to accomplish some tremendous tasks.

There is no doubt that many have given of their very best to the country, and as a nation we have achieved a great deal more than is obvious to the general public; but at the same time far more could have been accomplished if the whole of the material and labour available had been organised on a thorough system, which would have prevented lamentable waste and delay.

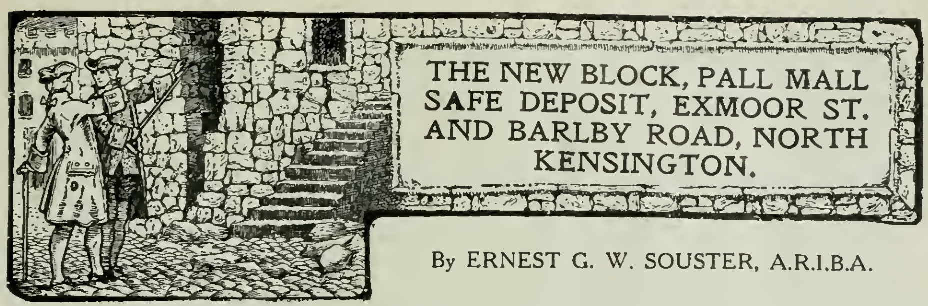
This fact probably applies as forcibly to the building and engineering trade as to any other, and when we consider the large amount of erection which has been undertaken and which was necessary for the production of munitions, the housing of men, and similar war purposes, it will be realised that these trades have played a very important part in the progress of the war. It is a well-known fact that we were unable to supply sufficient munitions at the commencement of hostilities, and, as the more extensive manufacture could not be proceeded with until additional buildings had been erected, it may be truthfully said that the speedy elimination of this undesirable state of affairs really lay, at the outset, in the hands of those responsible for the construction of munition and similar factories. Now we do not consider that the lack of co-operation in engineering work has been more noticeable than in any other particular type of work, but nevertheless there has not been sufficient co-operation, and both the individual and the community as a whole have suffered. In times of peace the independence and sense of isolation amongst engineers is very marked, and it has been deplorable, because the progress of the profession as a whole has been retarded; but what is merely deplorable in times of peace becomes almost criminal in times of war, and it is to be hoped that all those in the engineering profession will realise this. The supply of steel has played a most important part in the speedy erection of buildings, and yet on all sides there is evidence of manufacturers, merchants, and engineers being at sixes and sevens with one another, while most valuable time is being wasted. The reason for this state of affairs is because each individual does not realise that this is *his* war which is being fought, that the buildings are being erected to produce materials for *his* protection, and that money wasted will be paid for out of *his* income.

It is time to sink all petty details and personal feelings which prevent the closest co-operation between the designer and merchant, for with such co-operation work will be speeded up to the maximum. Many difficulties face the engineer who has prepared careful and numerous calculations for steel or reinforced concrete construction to be executed under war conditions. The particular sections he proposes to use are possibly not available from the firm supplying the material, and no definite promise can be given as to the date when such sections can be obtained from the rolling mills on account of the numerous orders to be executed. This generally leads to lengthy and unnecessary correspondence and waste of time, with the result that the building is delayed, when by proper co-operation other sections might be substituted, or the required material be obtained from stock through some other source. We have actually known such cases where important work has been delayed for months owing to a statement that certain material was not available, and at last proper enquiries have been made and some co-operation between all interested parties has been arranged, with the result that it is found that the material required could actually have been obtained from stock at the very beginning, but the cost was a little more; and, although it would have been willingly paid, the matter was not brought to the notice of the responsible party merely through lack of co-operation.

There have been numerous instances of delay caused by such misunderstandings as this, and it is for this reason that we advocate more co-operation. Engineers should assist one another, and they in turn should be in close touch and work in harmony with manufacturers. They should treat the work as being their own, and realise that they have a duty to perform apart from the work actually called for in the ordinary way by the payment of fees.

In the early stages of the war the traffic problem was a serious one, but practically all the difficulties met with have been overcome by co-operation. This co-operation has been brought about by the Government, who have arranged a system whereby the responsible person on each scheme is brought into direct touch with those responsible for the traffic, and even on the largest of building schemes there is practically no delay caused in the traffic which is not absolutely unavoidable.

It is possible that the various institutions which have suspended some of the normal and routine work could assist their members by acting as the centre from which information as to available stocks and various sources, dates of rolling sections, and similar data could be issued. They might also do much in organisation work applicable to the exceptional circumstances under which work is being executed, and it then rests with every individual connected with the engineering and building industry to do his best to secure proper co-operation between the parties who are designing, supplying, and erecting the essential parts of every structure. Some records have been created during the past twelve months, both as regards speedy erection and as regards slow progress, and in the latter cases we venture to state that the chief cause of delay has been the lack of proper co-operation.



THE NEW BLOCK, PALL MALL SAFE DEPOSIT, EXMOOR ST. AND BARLBY ROAD, NORTH KENSINGTON.

By ERNEST G. W. SOUSTER, A.R.I.B.A.

The need for fire-resisting construction in a building such as the one here described is, of course, of the highest importance, owing to the special risks incurred; and reinforced concrete, therefore, lends itself admirably for this class of building. The fact that this new block is built under the L.C.C. regulations for reinforced concrete is also of special interest.—ED.

THIS building is of great interest, as it furnishes a striking example of the differences that arise in designing a structure under the L.C.C. regulations and those in vogue on the Continent. When the first block was erected in 1911 no official regulations had been issued by the L.C.C. as to their requirements for reinforced concrete constructions, and the building, therefore, fairly closely conformed to what would be allowed in France. The second block, which has just been finished, is in strict conformity with the L.C.C. Amendment Act rules relating to reinforced concrete buildings, and *Fig.* 2, a cross section through the two blocks, shows how stringent our regulations are compared with Continental ones; for it will be seen that no secondary beams occur in the first block, and also that the columns are of smaller diameter.

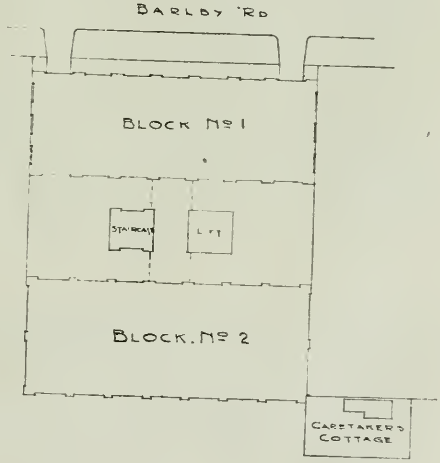
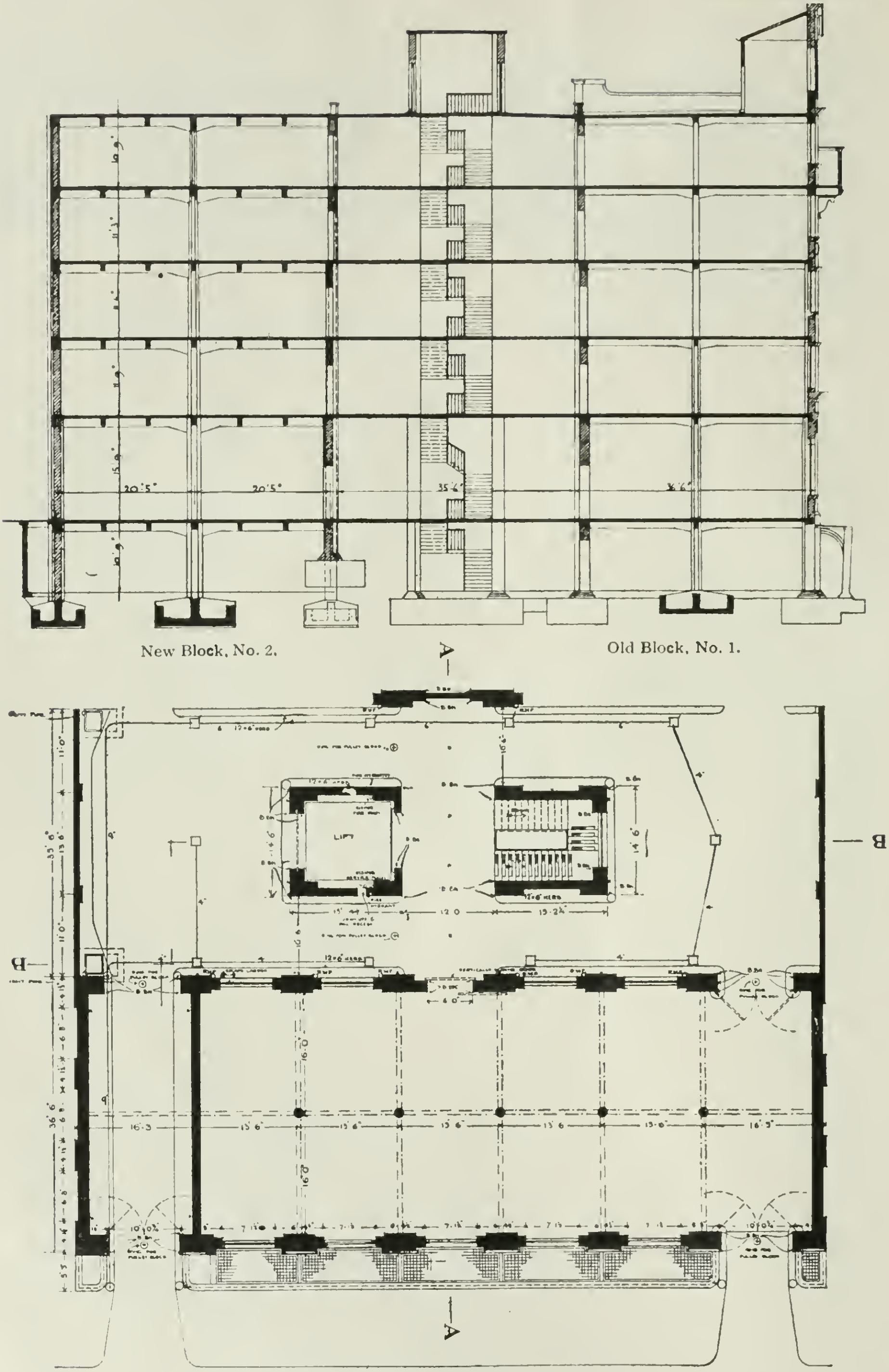


Fig. 1. Block Plan.
THE NEW BLOCK, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

Apart from this question, however, the structure is well worthy of study from the fact that it is a model example of a depository building. It is designed as a complete reinforced concrete frame, and, as will be seen from the plan, *Fig.* 3, every floor is constructed as a separate building in itself; thus each block contains six self-contained units. The staircase and lift giving access to them are kept free from the parts used for storage, and this elimination of stair and lift wells running from bottom to top of building greatly obviates the risk of fire spreading from one floor to another.

How great this danger is may be appreciated from the fact that the fire insurance companies have regarded each floor of each block as a separate building, thereby enabling them to accept a rate very considerably below the normal, not only for the structure itself, but also for what is of far greater importance, the whole of the contents stored therein.



Figs. 2 and 3. Section and Plan.
The New Block 2, Pall Mall Safe Deposit, Barlby Road, Kensington.

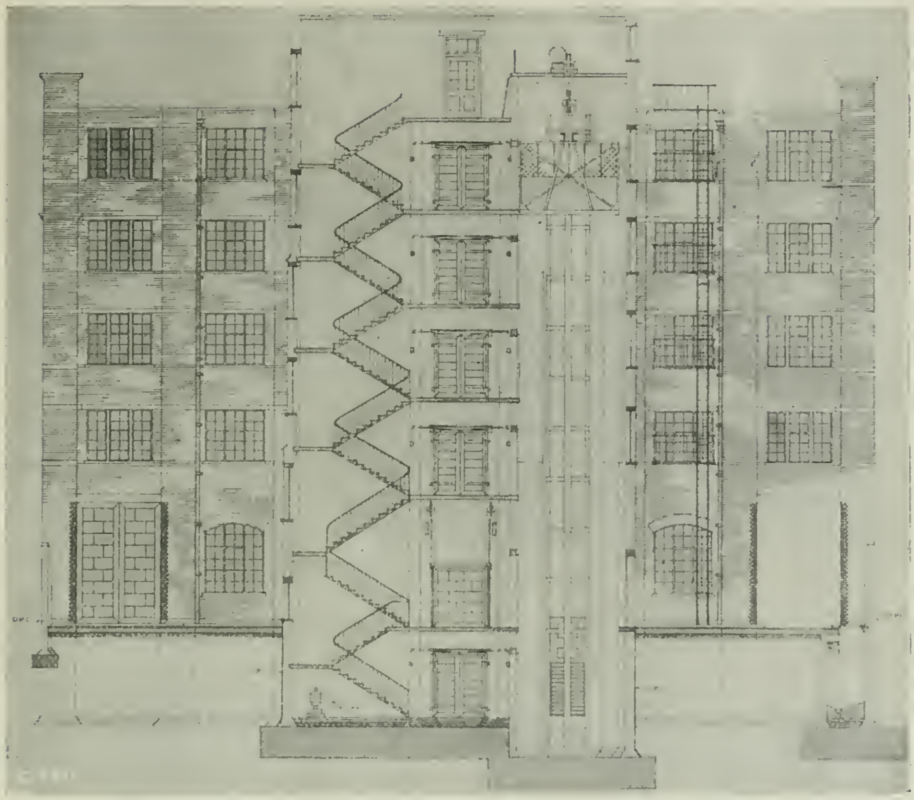


Fig. 4. Section through Area, showing Lift and Staircase.

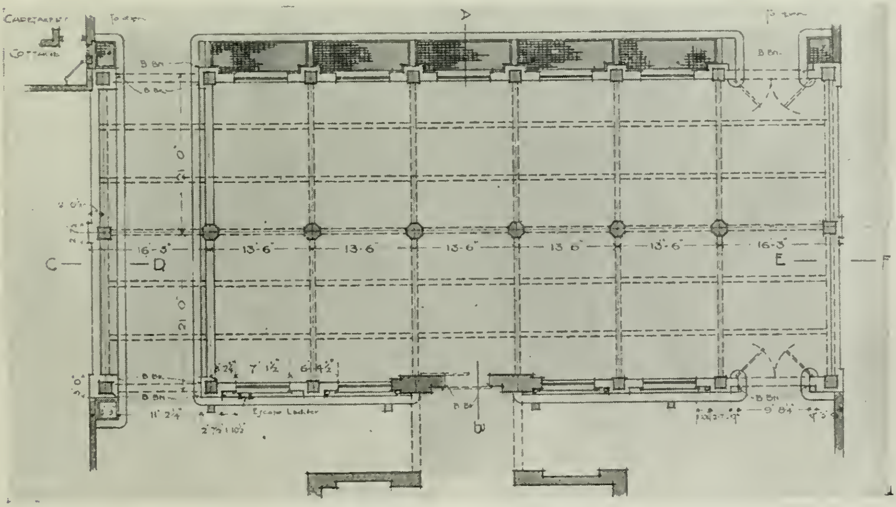
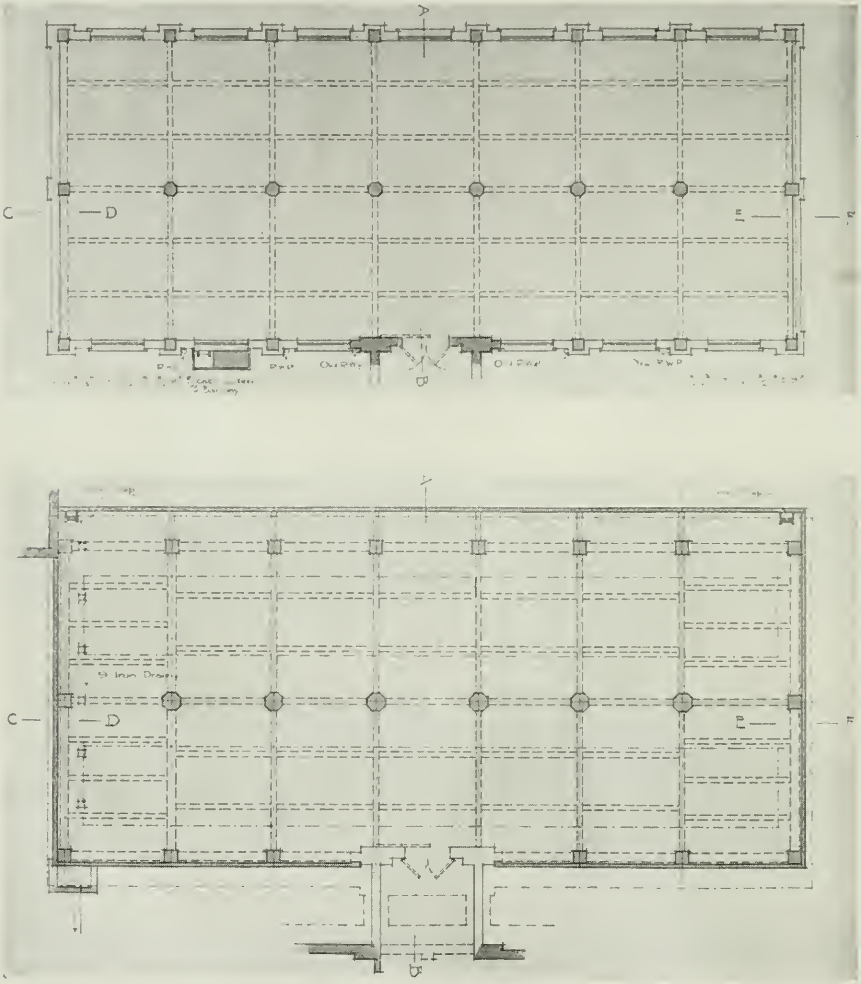


Fig. 5. Ground Floor Plan.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

A reference to the drawings, *Figs.* 1 and 2, shows that the building consists of two blocks, 100 ft. by 36 ft. 6 in. and 100 ft. by 42 ft. respectively, with an open area 35 ft. 6 in. wide between them. In this area are placed the staircase and lift, and bridges of fire-resisting construction, 12 ft. 6 in. wide, lead from them to the floors of depositories. Double iron doors cut off each of these units from the bridges themselves, and, as a further means of safety, hydrants are placed at each floor level upon the bridges.



Figs. 6 and 7. Plans.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

As already stated block 1 was erected some time ago, and the constructional details here given deal entirely with block No. 2.

The foundations of the building needed careful designing, for the site had

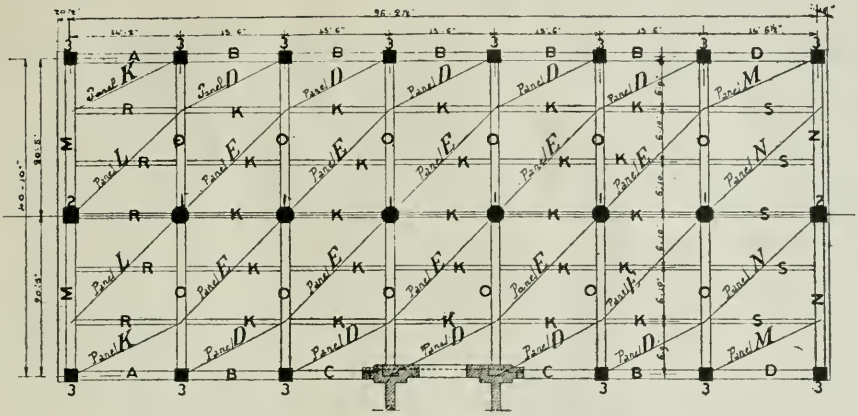


Fig. 8. Typical Plan of 1st, 2nd, 3rd, and 4th Floors.

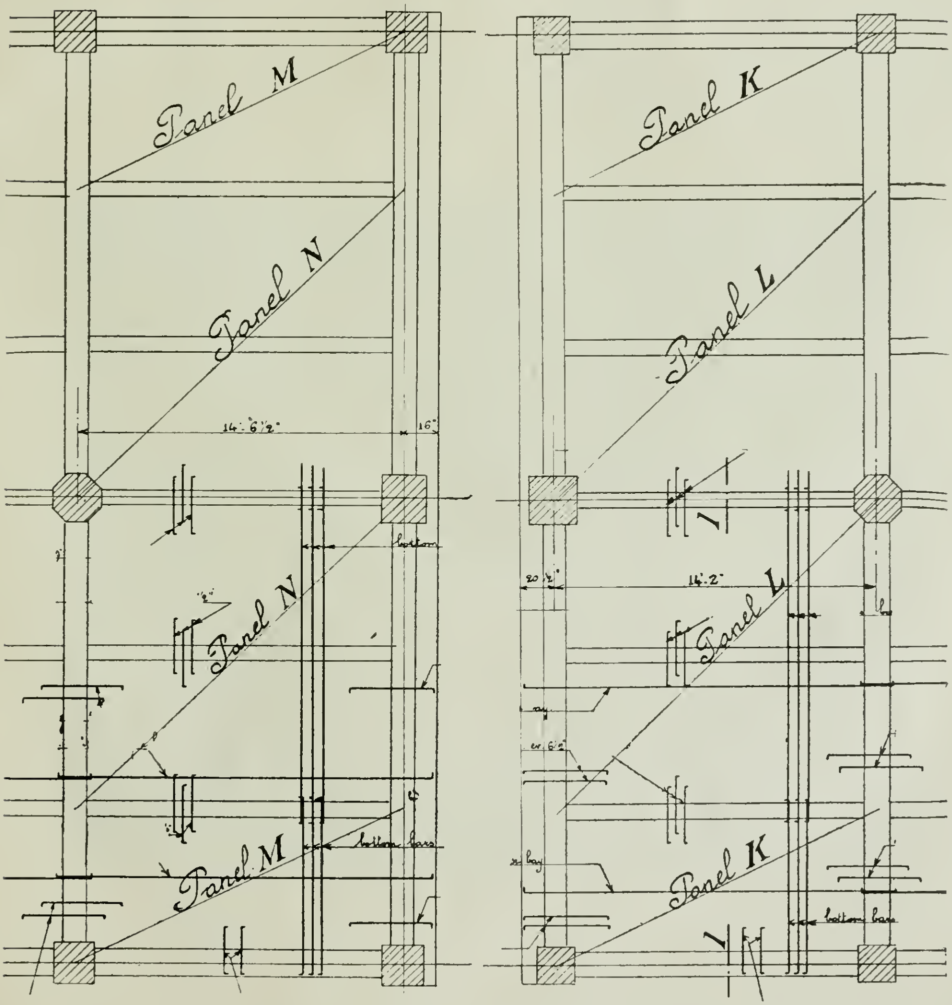


Fig. 9. Details of Floor Slab Armouring.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

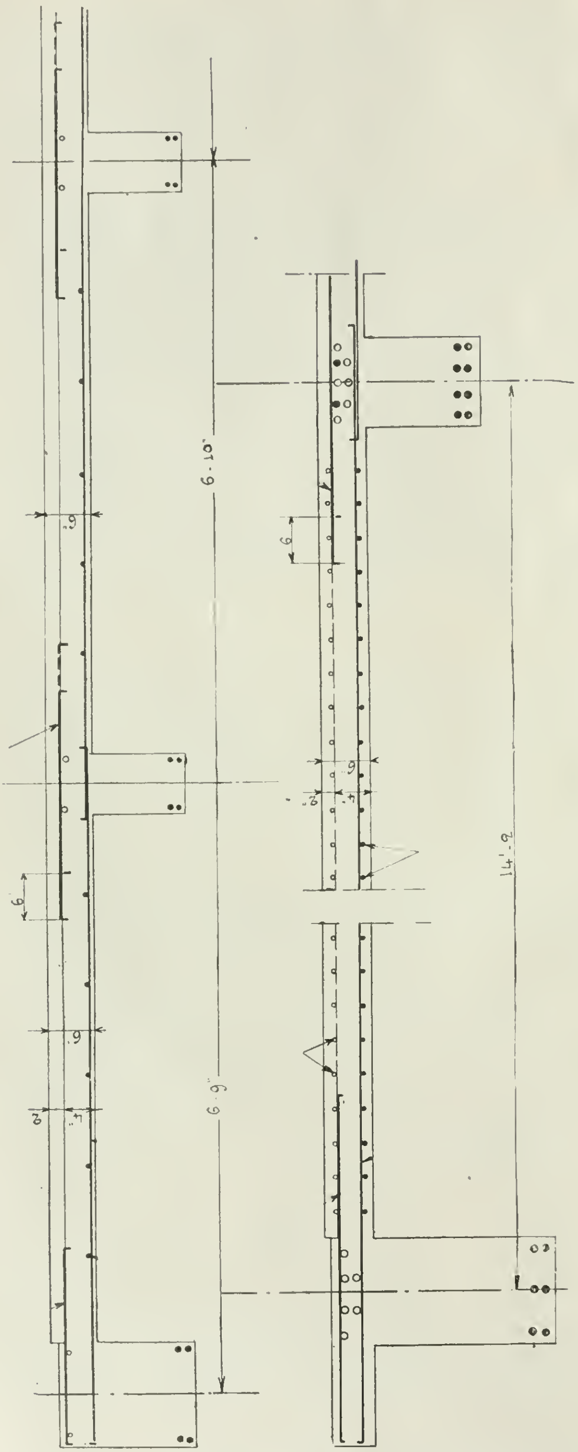


Fig. 10. Transverse and Longitudinal Beams.

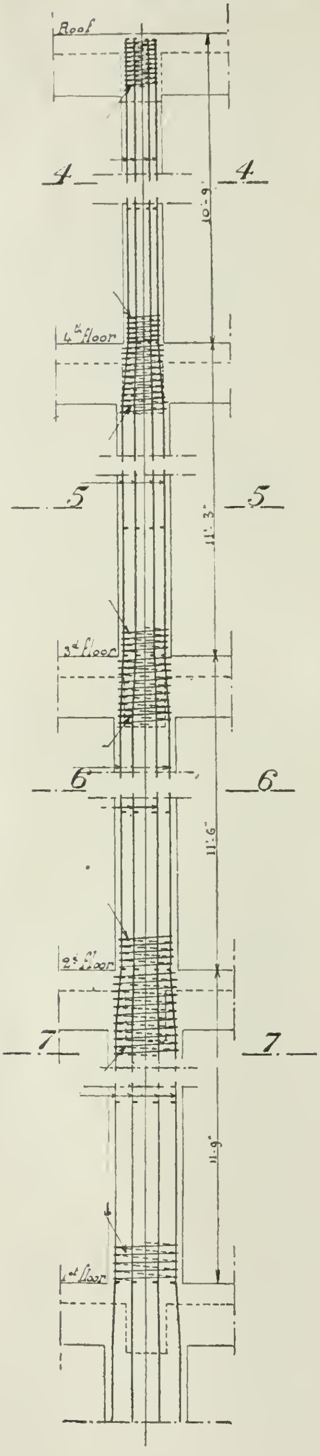


Fig. 11.
Elevation of Centre Columns.

THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

been used some years ago as a rubbish and sludge tip, and, moreover, a disused main sewer ran through the centre of the area. The joints of the brickwork of this sewer were in many places open, and thus it was still collecting water from some places and allowing it to escape in others, and the ground

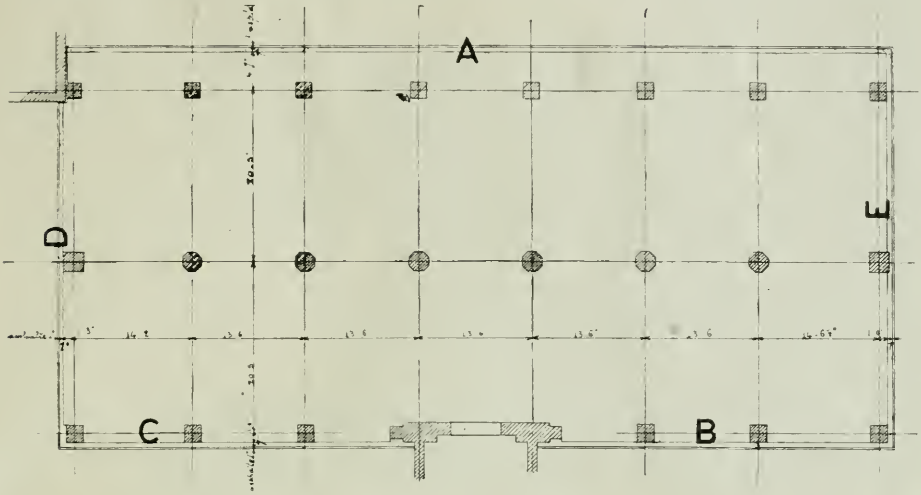


Fig. 12. Sectional Plan of Retaining Wall.

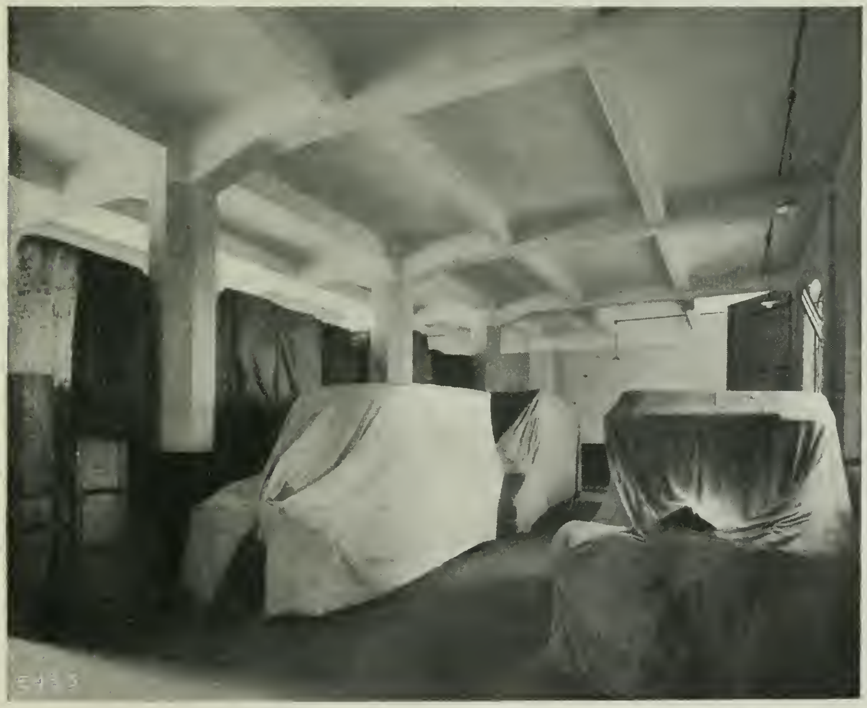


Fig. 13. An Interior View.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

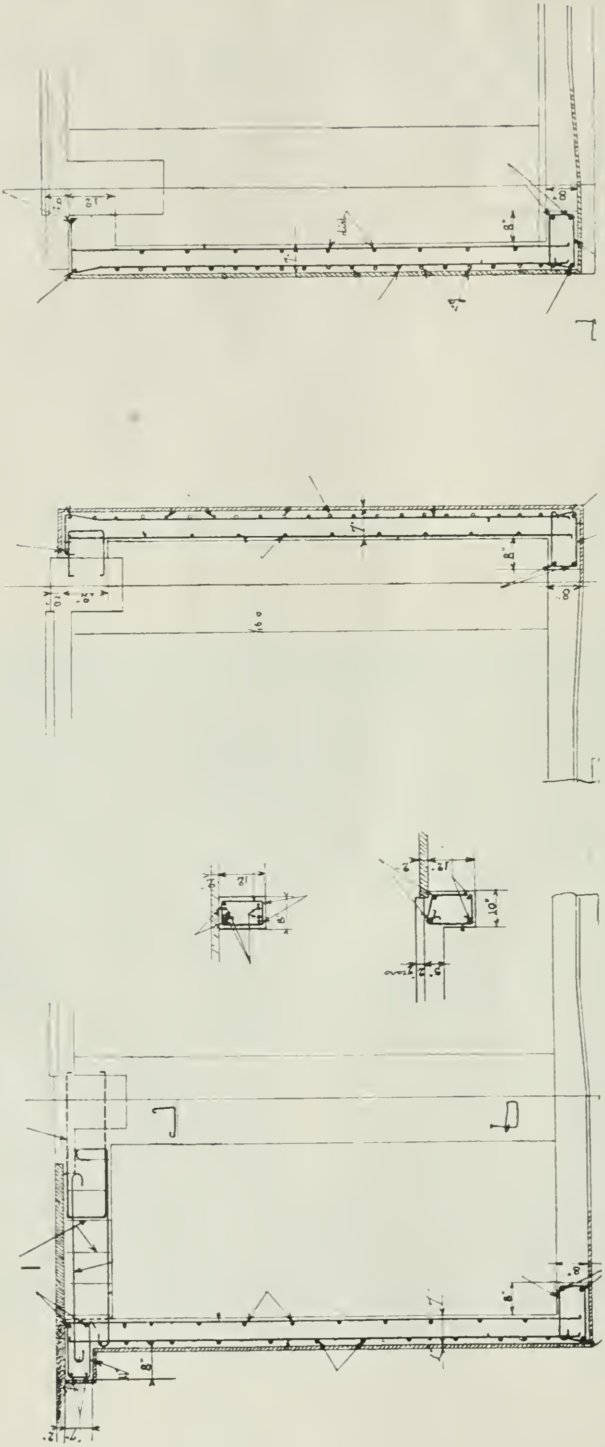


Fig. 14. Section through Retaining Wall.

The New Block 2, Pall Mall Safe Deposit, Barlby Road, Kensington.

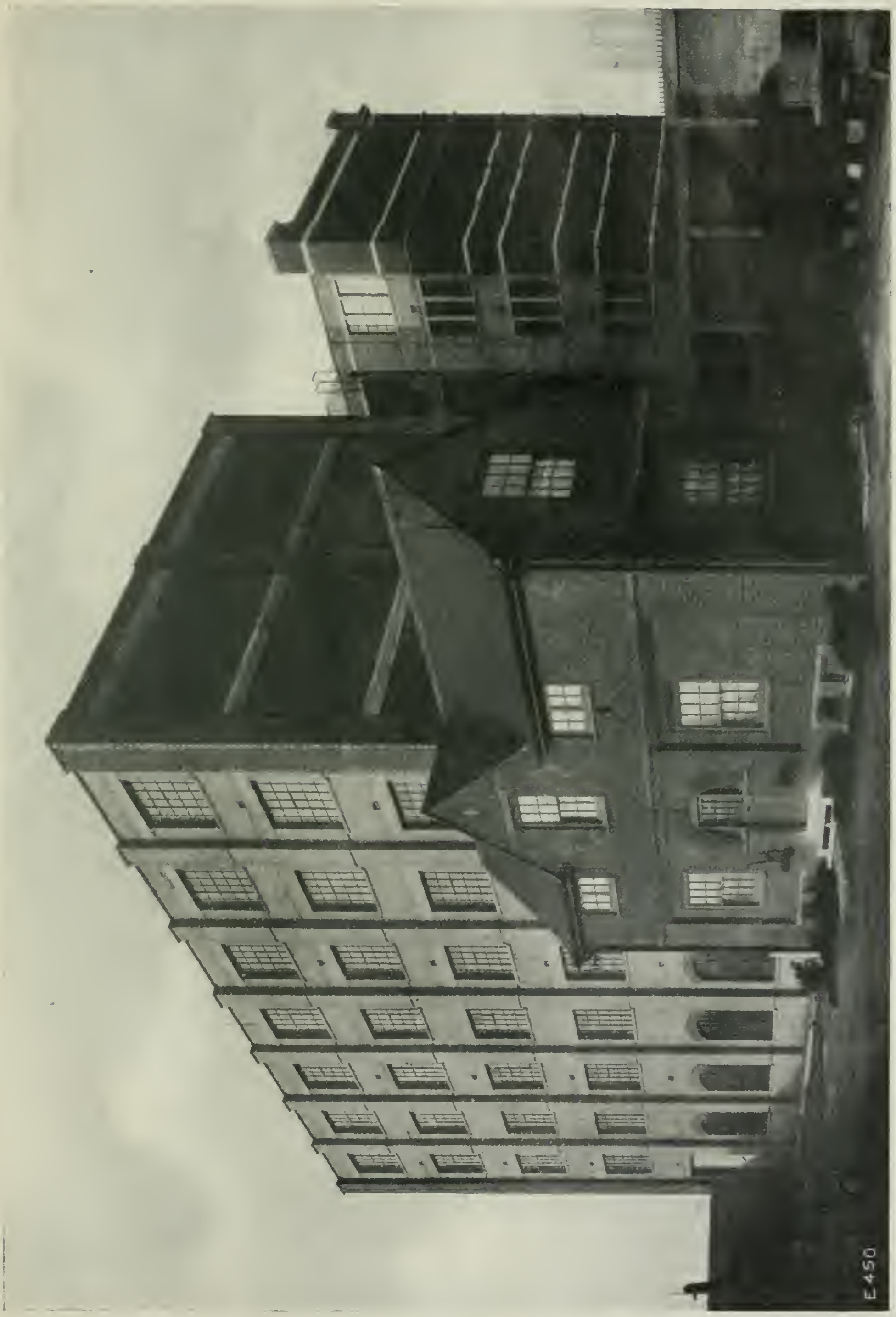
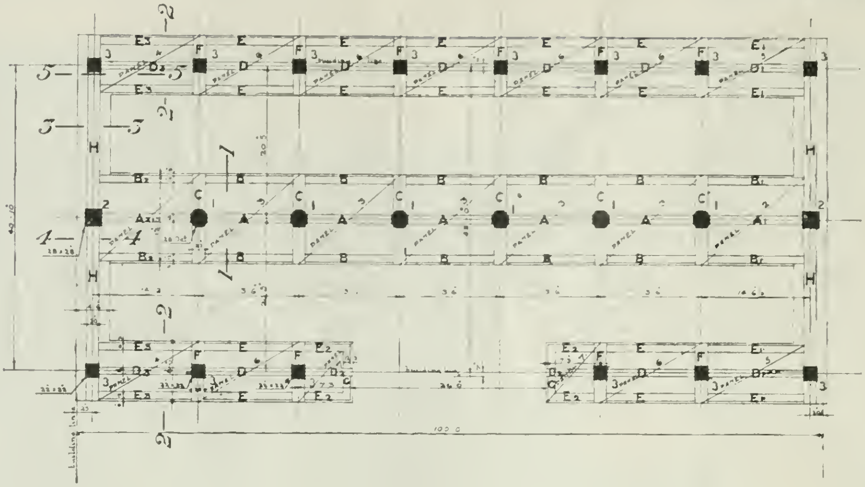


Fig. 15. Exterior View of Completed Building looking on to Exmoor Street.
The New Block 2, Pall Mall Safe Deposit, Barlby Road, Kensington.



Setting out Plan.

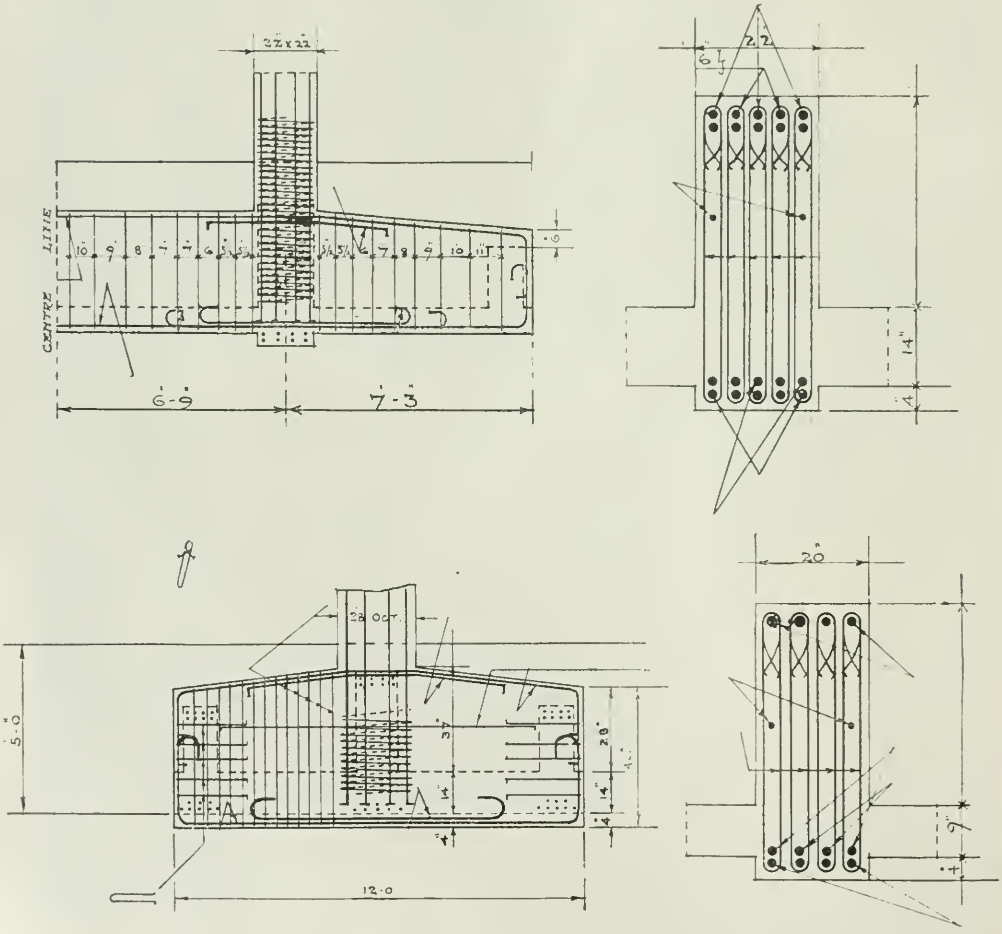


Fig. 16. Reinforced Concrete, Details of Foundations.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

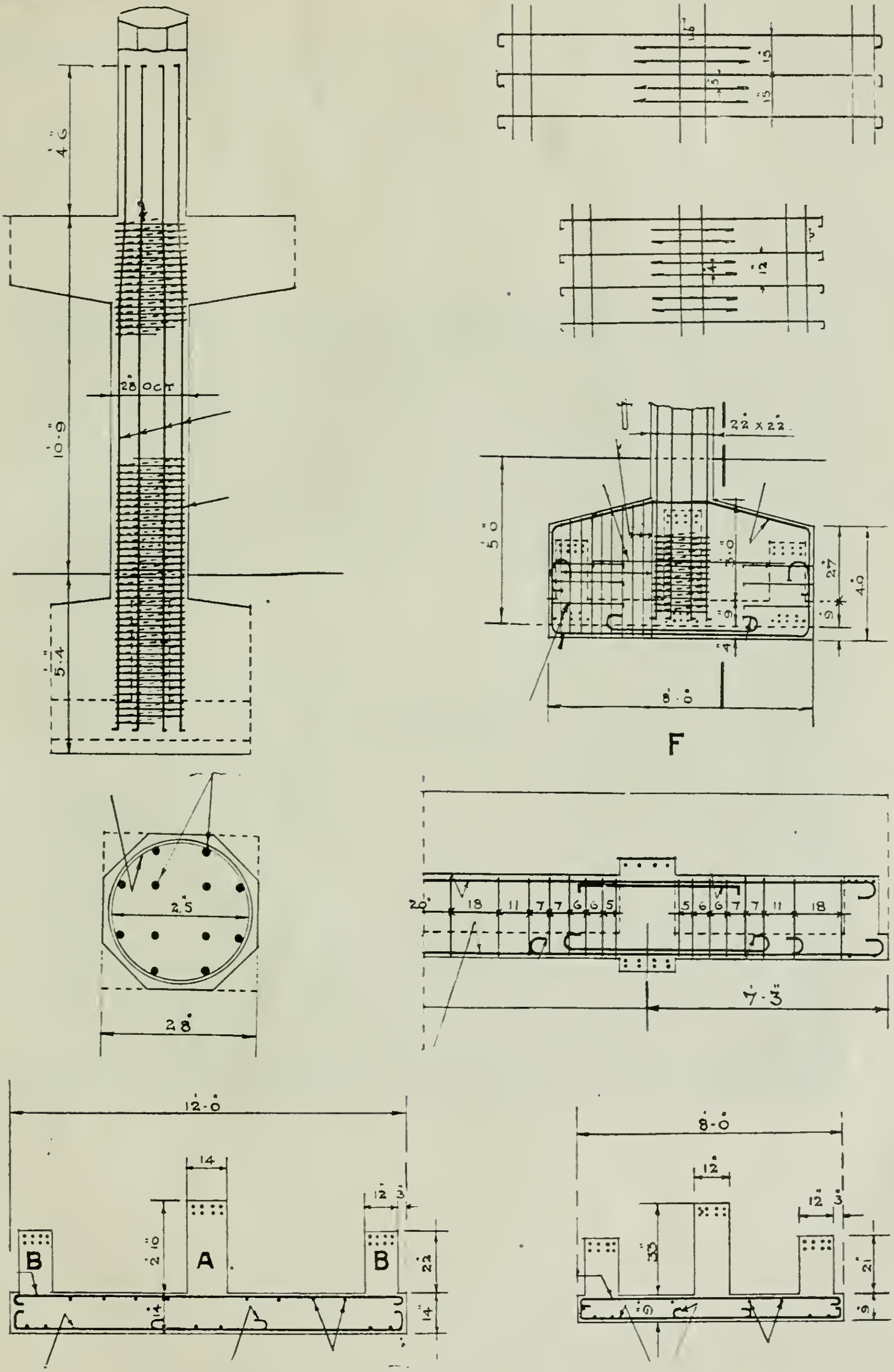


Fig. 17. Reinforced Concrete, Details of Foundations.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

was found to be so waterlogged that a sump has had to be formed to overcome possible trouble. This sump is below the lift pit, and an electric pump discharges the water which collects there into the neighbouring storm water sewer.

Figs. 16 and 17 show the foundation plan and sections through the inverted T foundations. As is indicated in these drawings the outer walls rest on foundations 8 ft.wide and 9 in. thick, with outer members 21 in. by 12 in., and central rib 33 in. by 12 in. The central row of columns is supported by a similar inverted T 12 ft. wide and 14 in. thick, having 22 in. by 12 in. outer ribs and 34 in. by 14 in. central ribs.

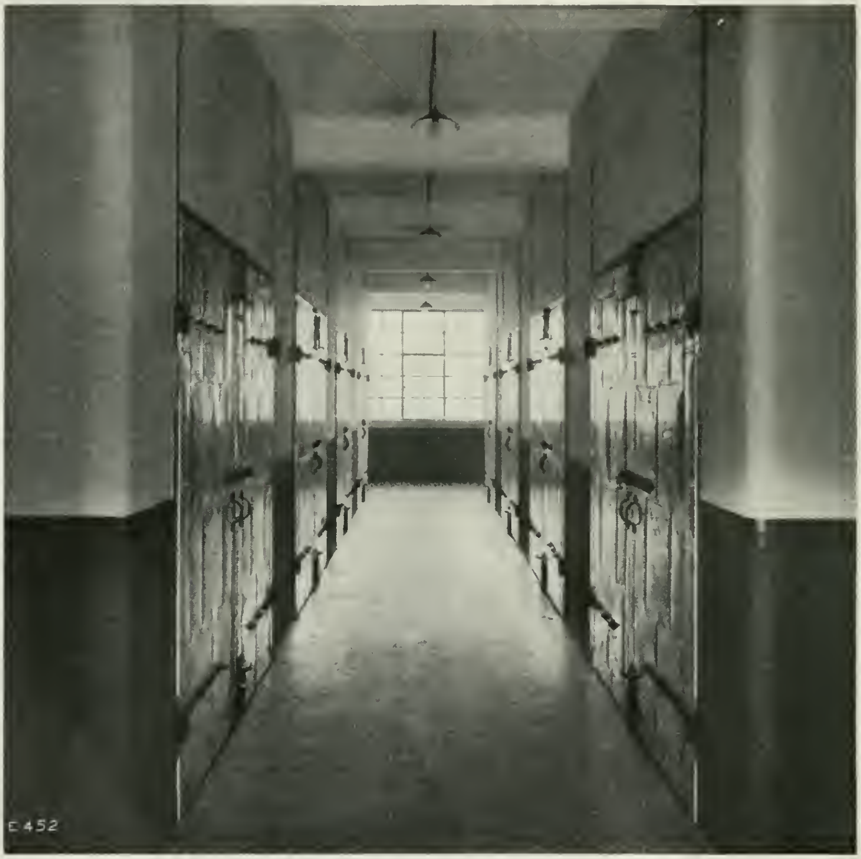


Fig. 18. View of Strong Rooms on 3r l Floor.
THE NEW BLOCK 2, PALL MALL SAFE DEPOSIT, BARLBY ROAD, KENSINGTON.

The end walls and piers rest on a similar foundation, 4 ft. 6 in. wide by 14 in. thick, with a central rib 34 in. by 20 in. No outer ribs are needed, and the central one is extended to receive the longitudinal outer members which are made homogeneous with it.

In order to better resist the pressure of the waterlogged earth the whole of the basement walls are constructed of reinforced concrete up to the ground floor level, and details of part of this wall are shown in *Figs.* 12 and 14. A layer of asphalte in two thicknesses is formed on the outside of this wall and is continued under the basement floor, which thus consists of 6 in. concrete, a layer of asphalte, a further 6 in. loading of concrete, and; finally, the granolithic finish.

Fig. 8 shows a typical plan of the upper floors of the building, from which it will be seen that each floor is divided into fourteen bays by a row of columns running longitudinally down the centre and with six main beams across the building. These columns are set out at 13 ft. 6 in. centres except in the end bays, where they are at 14 ft. 2 in. and 14 ft. 6 in. centres.

Each of these bays is again divided into three by longitudinal secondary beams. *Fig.* 9 gives the method of construction of the floor slabs and their means of connection to the beams, whilst *Figs.* 10 and 11 give details of the columns running down the centre of the building. Each column is formed with twelve vertical rods, eight of them placed octagonally near the outer surface and the remaining four forming a square towards the centre and stopping off at the third floor level. These columns have also spiral reinforcement for their whole length, and where joints are necessary in this spiral the overlap is made a minimum of half the circumference, and the ends of bars are then taken to the centre of the columns and finished with hooked ends.

The roof is similarly constructed to the floors and is designed to carry a load of 1½ cwt. per ft. super, and is finished with asphalte in two layers. Throughout the building the reinforced floors are 5 in. thick and are finished with 1½ in. granolithic above this.

The whole of the external walls of the building are built in panels carried independently at each floor level, and are of 14-in. brickwork in cement mortar with the tie beams between the pillars showing on the face.

The building is equipped throughout with a vacuum cleaning system and is lighted by electric light, the current for which, as well as that for all power purposes, is supplied by an electric generating plant on the premises.

The architect for the work was Mr. W. G. Hunt, F.R.I.B.A., of 17a, Vicarage Gate, Kensington; the general contractors were Wm. F. Blay, Ltd., of Dowgate Hill, Cannon Street, E.C., and the whole of the reinforced concrete work was carried out in accordance with the system of the Considère Construction Co., of 5, Victoria Street, S.W.

RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

Continued from June issue, p. 305.—ED.

PART III.

(*a*) *STATEMENT OF ORDINARY THEORY AND FORMULÆ.**

1. *Resistance of concrete to diagonal tension.*

Consider a small square element in the web of a beam subjected to shear (*Fig.* 14).

The vertical shear in the beam produces shearing stresses S_1 on vertical planes. If these were the only forces acting on the element it would rotate. To keep it in equilibrium there must be an equal shear stress, S_2, on the horizontal planes.

If these shear stresses are combined, it will be seen that they are equivalent to a principal compressive stress on one diagonal plane and a principal tensile stress on the other, both stresses being equal in intensity to the shear stress.

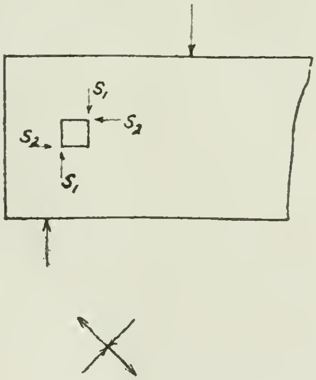


Fig. 14. Analysis of Shear Stresses.

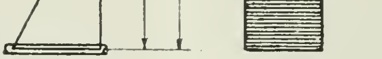


Fig. 15. Distribution of Shear Stress across a Vertical Section of a Reinforced Concrete Beam.

Since concrete is far weaker in tension than in either compression or shear, it tends to fail along the tension plane, and the limiting value for the shear resistance is then—

$$S = t\ b\ a$$

where t is the safe tensile strength of the concrete generally taken as 60 lb./in.^{2}, b and a are the breadth and the arm of the resisting couple in the beam respectively. The formula may therefore be written—

$$S = 60\ b\ a.$$

---

* This is a very short précis only. More complete arguments are given in Faber and Bowie's "Reinforced Concrete Design," pages 79–83.

The reason for taking the maximum stress over the area $b\ a$ and not over the area $b\ d$ is that the shear on vertical planes is not constant, but varies as a parabola from the top down to the neutral axis, as shown in *Fig.* 15. Remembering that the area of a parabola is two-thirds of the rectangle enclosing it, it will easily be seen that the area of the shear stress curve above the neutral axis is the same as if the shear stress were taken up at its maximum value to the centre of compression, as shown dotted in *Fig.* 15.

It has recently been felt that there is some theoretical objection to considering the tensile stress as acting on the whole area $b\ a$, since the elongation which must take place before the steel can take up its stress forces the concrete to crack along lines as shown in *Fig.* 18, which theory indicates must extend to near the neutral axis, even if they are not visible.

It is obvious that once these cracks have been produced by the action of the reinforcement resisting what may be termed flange stresses, it is not permissible to consider the shear as resisted by tensile stresses across such surfaces.

This was undoubtedly the reason for the following regulation in the draft dated 23/7/14 of the L.C.C. Regulations :—

> "66.—The vertical shear taken by the concrete only shall be calculated on the compressed area of the web, or on the web area for a depth equal to *one-half* of the effective depth of the beam or slab. The intensity of the shearing stress shall not be greater than the values given in Regulation 42."

The practical effect of this is to reduce the safe shear resistance, when no web reinforcement is provided, to 30 $b\ a$ or less, which is much lower than has been required by any other regulations.

It will be seen later that in the writer's view this value may often be exceeded with perfect safety.

In the final regulation this draft regulation has, however, been amended back to the whole area $b\ a$ (Regulation 64).

2. *Resistance of bent-up bars.*

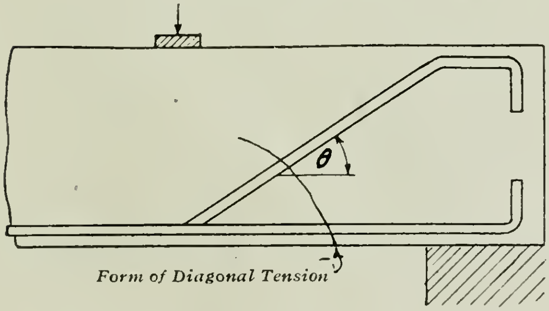


FIG. 16. RESISTANCE OF BENT-UP BARS TO SHEAR.

When part of the main reinforcement is bent up near the end of a beam as in *Fig.* 16, it will cut the planes of diagonal tension, by which failure will otherwise occur.

It is assumed in common practice that the bar may be considered as stressed up to its safe stress, in which case, of course, its resistance to vertical shear is—

$$S = t\ A \sin\theta$$

where t is the safe tension stress (16,000),
A is the area of inclined bar,
θ its inclination to the horizontal.

3. *Resistance of stirrups.*[*]

The action of stirrups in resisting shear in a beam is to be understood by considering them as the vertical tension members of a lattice girder, the diagonal compression member being formed by the concrete in the web of the beam (see *Fig.* 17).

---

[*] The writer believes that this is a rather generous exposition of the ordinary theory as generally understood. Note, for example, Appendix II. to the R.I.B.A. (1911) Report, which is based on the *shearing* strength of the stirrups, whereas it has been proved experimentally (and is clear from theoretical considerations) that their action is in tension, and that if put into shear they would crush the concrete on their edge before their strength were developed.

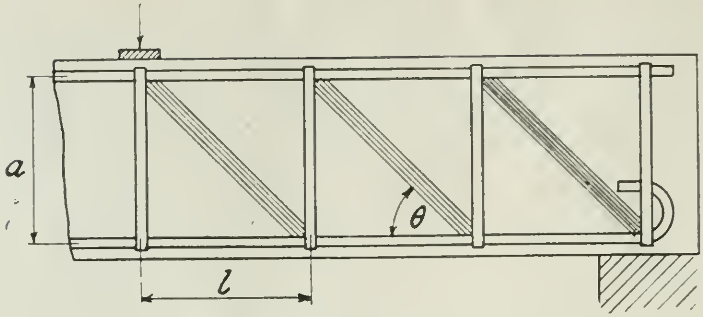


Fig. 17. Shearing Resistance of Beams with Stirrups.

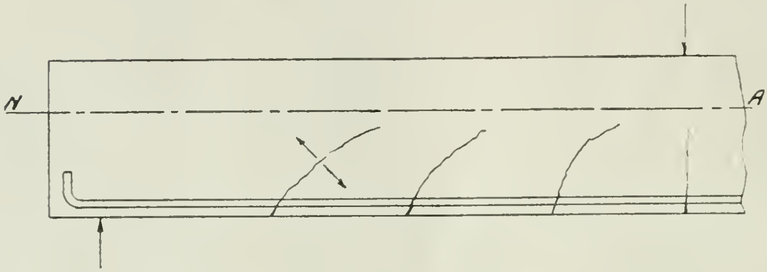


Fig. 18. Action of Cracks Produced by Stretching of Flange Reinforcement and in Reducing Strength in Diagonal Tension.

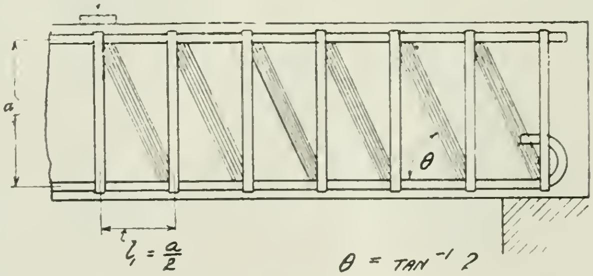
Consider first the case when the spacing of the stirrups l is equal to the arm of the resisting couple a, and the diagonals are inclined at

$$\theta = 45^\circ$$

It is obvious that under these conditions the tension to be resisted by each stirrup is equal to the total shear across the section (or such proportion of it as is to be carried by the system of stirrups)

Suppose now that the stirrups are placed twice as close. The stress in the stirrups will depend on whether we consider the system as a single one with the inclination of the diagonals doubled, as in *Fig.* 19 (*a*), or as a double one with the inclination at 45°, as before as in *Fig.* 19 (*b*).

In the former case it will be seen that the tension per stirrup is still equal to the total shear.



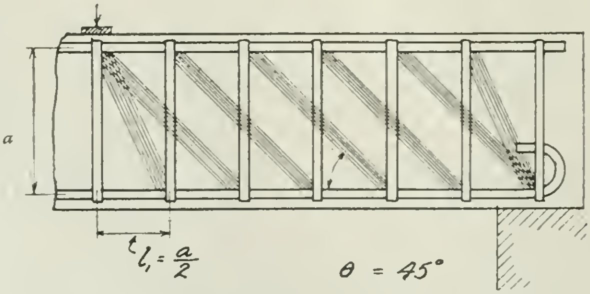


Fig. 19. (*b*) Close Stirrups Acting as Double System.

In common practice it is assumed that the inclination will remain at 45°, in which case the safe resistance to shear increases in proportion to the closeness of the stirrups, or, if we put

A = area per stirrup,
l = spacing,
a = radius arm of resisting couple,
t = safe tensile stress in stirrups,

the safe shear resisted by stirrups is—

$$S=\frac{A\ t\ a}{l}$$

A proviso is made that the spacing l must not exceed the radius arm.

4. Combination of 1, 2, and 3.

In most regulations, but not in draft L.C.C. Regulations, and to the writer's certain knowledge in the practice of most so-called reinforced concrete specialists, it is customary to deal with combinations of 1, 2, and 3 by the process of simple addition, which certainly has the merit of simplicity, and perhaps that alone.

For example, in a beam containing stirrups and bent-up bars, the calculations take some such form as the following:—

	Shear Resistance.
By concrete	$60\ b\ a$
„ bent-up bars	$16{,}000 \times A \sin\theta$
„ stirrups	$16{,}000 \times \frac{A \times a}{l}$
Total	

and provided this total shear resistance is at least equal to the shear across the section, conditions of safety are supposed to be satisfied.

Note in this connection the following extract from the Second Report (1911) of the Joint Committee of the Royal Institute of British Architects, which has been used as a standard for several years (page 14):—

"When S, the total shear in lb. at a vertical section, does not exceed $60\ b\ a$, no shear reinforcement is required.

"When S exceeds $60\ b\ a$, vertical shear members may be provided *to take the excess*, and proportioned by the following rule:—

$$\frac{A_s\ s_s\ a}{p}=S-60\ b\ a$$

$$A_s=\frac{(S-60\ b\ a)\ p}{a\ s_s}$$

where s_s is the unit resistance of the steel *to shearing* and p is the pitch or distance apart of the vertical shear members or groups of shear members, of area A_s."

It will be seen that besides adding the resistance of the concrete to that of the shear reinforcement, the efficiency of the stirrups is considered to be limited by their resistance to shearing.

The writer hopes to show later that the first is quite wrong, and that the action of the stirrups is one of tension, and not of shearing.

(b) STATEMENT OF THE WRITER'S THEORY.

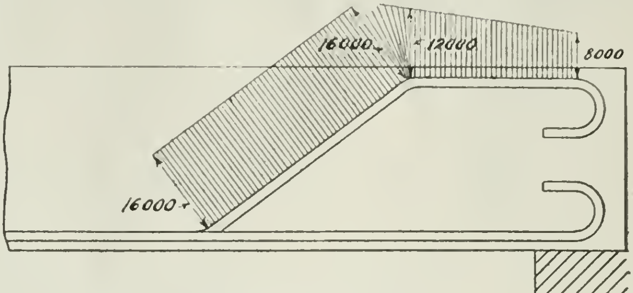
1. Resistance of concrete to diagonal tension.

The writer is in general agreement with the analysis just given under this head, and believes that in very long beams with no shear reinforcement the safe shear across a vertical section may be limited by diagonal tension, in which case the formulæ given are applicable.

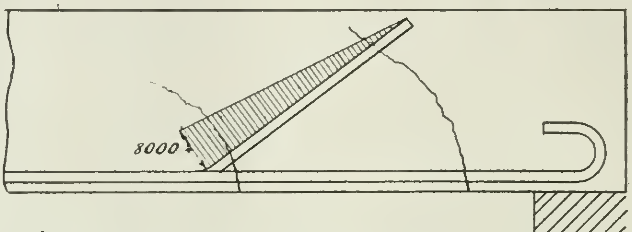
In nearly all practical cases, however, the writer believes that a much greater resistance to shear will be provided by the formation of a "direct inclined compression" as explained later.

2. Resistance of bent-up bars.

Similarly with inclined bars the writer approves the use of the method outlined, provided certain precautions are taken. The most important of these is that the bent-up bar shall be adequately fixed at both ends to prevent slipping. It is not difficult to see that for the formula given to be correct the assumed stress must actually exist in the bar for the whole of its inclined length.



(a) WELL SECURED BENT UP BAR



(b) BADLY SECURED BENT UP BAR

Fig. 20. Typical Diagrams of Tensile Stress in Bent-up Bars.

Consider, for example, *Fig.* 20, showing two typical distributions of tensile stress in bent-up bars. In the top one (*a*) the efficient hook at the end develops a stress of, say, 8,000 in the bar, and this is gradually increased by adhesion to 12,000 along the horizontal portion. The friction at the bend—similar to that of a belt round a pulley—will increase this to the safe stress of 16,000, which is maintained through its inclined length.

At this point its stress will be determined by considerations of bending moments and the friction on the bend will enable it to alter its stress here if necessary. As a rule, no great change is necessary here, as the bar is usually bent up where the bending moment diagram allows of it.

Consider now the bottom one (*b*); the stress at the top end is necessarily zero, and it can only increase gradually as determined by adhesion. In most practical cases it will not even have reached $t=16,000$ at the lower end, but perhaps only 8,000, depending on its length and diameter.

In that case the resistance of the bar to shear should only be taken on a basis of $t=8,000$ if we are considering failure on the surface 1, or $t=\text{zero}$, if we are considering failure on the surface 2.

If some apology is needed for the length of this statement, the writer offers the fact that many designers do not appreciate this point sufficiently, and quite often—as, for example, with the prongs of a well-known patent bar—provide no fixing at all.

The writer also feels that some limit must be put to the resistance to shear which can be obtained in this way, since the resultant of the tension in the inclined and horizontal portions of the bent-up bar can only be equilibriated by an inclined compression force, and a limit will be reached when failure or bursting of the concrete resisting this force will occur before the steel is overstressed.

This applies also to the hook or bend at the top end of the bent-up bar.

This limit will be discussed later.

The writer would also add that whereas in common practice and in all regulations with which he is acquainted the resistances to shear of bent-up bars is limited to the length of beam in which the bar is inclined, in his opinion the inclined compression produced by the resultant of the tensions of inclined and horizontal portions of the bent up, give a resistance to shear in the adjacent panels which much increases the value of such an arrangement of reinforcements. This also will be dealt with more fully later.

3. With *stirrups*, the writer agrees the substantial correctness of the usual theory and formula as explained, provided certain precautions are taken. For exactly the same reason as explained above, the stirrups must be adequately secured both ends; otherwise, if fixed at the bottom and not at the top—a common arrangement—the stress will be zero at the top, gradually increasing towards the bottom at a rate determined by adhesion, very different from the constant stress of 16,000 assumed by the formula.

In the matter of the all-important angle of θ of the diagonal forces with the horizontal, the writer is not satisfied with the tacit assumption of 45° in all cases.

In his view, the following considerations will govern this angle :—

It will have been noted in (*a*) 3, that the smaller this angle the greater is the efficiency of a given arrangement of stirrups in resisting shear. The writer takes the view that : *In a complex combination of members which may act in several ways failure will not occur until the members act in such a manner as to produce the maximum resistance to failure consistent with absence of overstrain in any member.*

By this is meant that if a complicated structure gives a certain safe load if analysed as an arch, a different safe load if analysed as a truss, yet a different one if analysed as a beam, and so on, it may be assumed in practice that it will act in that manner which gives the greatest safe load on analysis. It goes without saying that in the calculation of the respective safe loads all the necessary conditions of safety must be satisfied; no arching action, for example, may be taken if the abutments have not the necessary resistance to the spreading action of the arch, this being expressed in the law as above written by the words " consistent with overstrain in any member."

If this general theory be accepted—and in practice it is tacitly assumed in all good design, though the writer has not seen it specifically stated—it will be obvious that where the resistance to shear is limited by the cohesion of the stirrups, the angle θ will become as small as is " *consistent with absence of overstrain in any member.*"

The two dangers attaching to the assumption of a small value of θ are :—

(1) Overstressing the concrete in compression.

(2) Causing sliding of the stirrups.

The first of these is considered later, where it is shown that c increases in proportion to $\frac{1}{\sin\theta\times\cos\theta}$, and its value may be kept within safe limits provided the total shear across the section does not exceed $cab\ \sin\theta\times\cos\theta$ in favourable cases of distribution.

Considering now the second, reference to *Fig.* 21 (*a*) will show that a bent-up bar of suitable design, even when vertical, is not subject to any slipping, whereas a stirrup, as in *Fig.* 21 (*b*), is.

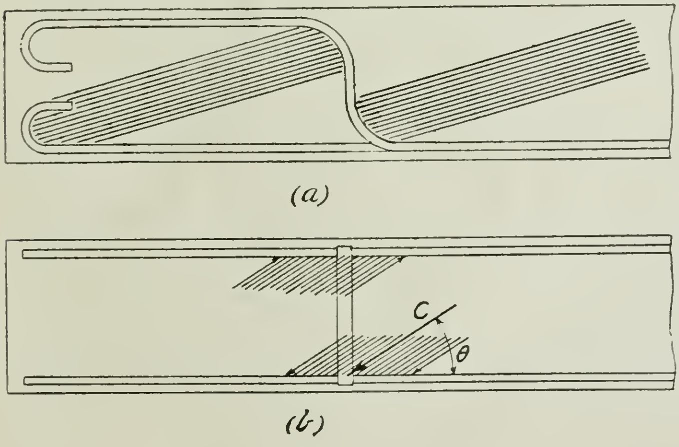


FIG. 21. TO ILLUSTRATE SLIPPING OF STIRRUPS.

Resolving the inclined compression C horizontally and vertically where it meets the bar, the vertical component P will be resisted by the stirrup, and the horizontal component is resisted by adhesion and friction.

$$P \cot \theta = \mu P + \text{adhesion}.$$

The adhesion is to be taken to include a horizontal compression in the concrete resisted by the hook at the end.

If, however, we neglect the adhesion for a moment we have—

$$\mu = \cot \theta$$

If we take the coefficient of an iron rod on concrete as 0·5 (it will be more for a rusty bar and less for a smooth bar) we have—

$$\theta = \cot^{-1}\tfrac{1}{2}$$

In other words, so long as θ is over $\cot^{-1}\frac{1}{2}$ (about 63·5°) there can be no question of slipping. At smaller angles, however, we are relying on adhesion to the extent of

$$\text{Adhesion} = P\left(\cot \theta - \tfrac{1}{2}\right)$$

Consider the case of a beam in which we have $\theta = 45°$ two bottom bars 1 in. diam., in a beam having the radius arm of the resisting couple 12 in. and the width 5 in., stirrups 4 strands 1 in. × ¼ in. at 12 in. centres

If we stress the stirrups to 16,000 we have—

$$P = 16{,}000$$
$$\cot \theta = 1$$

Hence—

$$\text{adhesion} = 16{,}000\ \left(1 - \tfrac{1}{2}\right) = 8{,}000 \text{ lb.}$$

Now the adhesion which can safely be developed in a length of 12-in. by two 1-in. bars is—

$$12 \text{ in.} \times 2 \text{ in.} \times \pi \times 100 = 7{,}530 \text{ lb.}$$

so that in this case the angle of 45° is just about safe.

It may be noted that 4 strands 1 in. × ¼ in. is very heavy shear reinforcement for a 12-in. × 5-in. beam, the shear across the section being

$$\frac{16{,}000}{12 \times 5} = 266 \text{ lb./in.}^2$$

whereas 300 lb./in.² is shown to be the absolute maximum for stirrups.

We may therefore conclude that the angle $\theta = 45°$ is safe in most practical cases.

4. It is chiefly in connection with the calculations for *combinations of the three preceding systems* that the writer takes exception to what is unfortunately too common practice.

It is obvious that the tension in bent-up bars cannot approach a figure of 16,000 lb./in.² without the corresponding strain, and at that strain the concrete will necessarily have cracked.

This will be realised when we consider that, retaining 15 as the modular ratio, the tensile stress in the concrete would otherwise approximate to

$$t = \frac{16{,}000}{15} = 1{,}066 \text{ lb./in.}^2$$

whereas its ultimate stress (in tension) is about 240, and its safe stress about 60.

It clearly follows that if we stress the steel to 16,000 the resistance of the concrete must be neglected, and if we rely on the concrete we must only stress the steel to

$$60 \times 15 = 900 \text{ lb./in.}^2$$

This has long been realised in the calculations for resisting moments, but is imperfectly realised in those for shear.

For exactly similar reasons the resistance to shear due to stirrups stressed to 16,000 must not be added to that due to concrete stressed to 60 lb./in., since the former condition requires the concrete to be cracked.

In both cases the cracks may be so small that they cannot be detected, as is the case in regard to bending, when the concrete can be proved to be cracked long before the cracks can be seen.

Coming now to a combination of stirrups and bent-up bars, there is no reason why they should not be effective simultaneously. Consider, for example, the arrangement of reinforcement, and the stresses induced in it by shear, shown in *Fig.* 22.

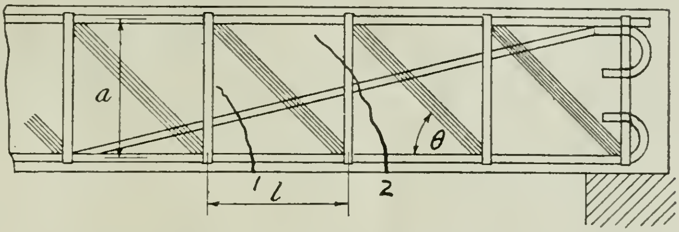


Fig. 22. Action of Bent Bars and Stirrups in Combination.

It will be seen that the opening of cracks on diagonal surfaces 1 and 2 does not in any way prevent the concrete from resisting the diagonal compression forces required to bring the stirrups into tension, while they are a necessary condition for the bent-up bars to be usefully stressed.

5. "*Inclined compressions.*"

A few years ago the writer realised that many beams would have a source of resistance to shear which is not included under either of the heads 1 to 3 (concrete in tension, bent-up bars, and stirrups), and to which he has given the name the "inclined compression" resistance. It was indicated in "Reinforced Concrete Design," pages 83 and 85, together with the conditions for its action and its limitations, but the matter was not dealt with sufficiently fully to be of much assistance to designers, nor was experimental evidence given of its correctness.

Since then the writer has had time to investigate it more fully, both analytically and experimentally, and he may, perhaps, be allowed to mention that the treatment suggested has for some years been used in his drawing office in connection with important structures.

It will have been noticed that in the preceding pages, suggestions have been made that inclined compressions must be produced in the concrete wherever bent-up bars or stirrups are called upon to resist shear, and in fact the only analysis of the action of stirrups which is worth serious study is one which is based on a study of this action.

It will be shown, first, that such inclined compressions sometimes oocur where neither bent-up bars nor stirrups occur, and calculations will be made to show the maximum shear which can be resisted in this manner.

We will then make a further study of inclined compressions in combination with bent-up bars and stirrups, which it is hoped will bring fresh light on the subject of resistance of beams to shear.

It will be convenient to refer to inclined compressions as "direct" when they pass from load to support without being lifted by tension members, and as "indirect" when they pass from the load to the bottom of a tension member which lifts them to the top flange, whence they again pass down towards the support, this lifting occurring as many times as may be necessary.

6. *Direct inclined compressions.*

Consider *Fig.* 23 (*a*) which shows a rectangular beam reinforced with straight tension bars with large hooks at the end and loaded with a central point load. Unless we are to overstress our material at the load and the supports, an appreciable area must be given to these, which is indicated in the drawing.

When the load is applied tensile stresses are produced in diagonal planes, and at a certain stage (corresponding to a tensile

$$\text{stress} = \frac{S}{b\,a} = \text{about } 240 \text{ lb./in.}^2\Big)$$

a crack will be formed on some surface (like *Fig.* 22) whether they are visible to the eye or not.

The conditions in the web then change completely and approximate to those which it is attempted to indicate graphically in *Fig.* 23 (*a*).

The tensile stress in the steel, instead of varying uniformly from a maximum at the centre to zero at the support, will tend to become more constant along its length and to die off in a much shorter length near the bearings (see *Fig.* 24).

The adhesion, instead of being distributed uniformly along the bar from mid-span to support, will tend to become very small during this length, and will be taken up rapidly at the end by the pressure of the hook against the concrete.

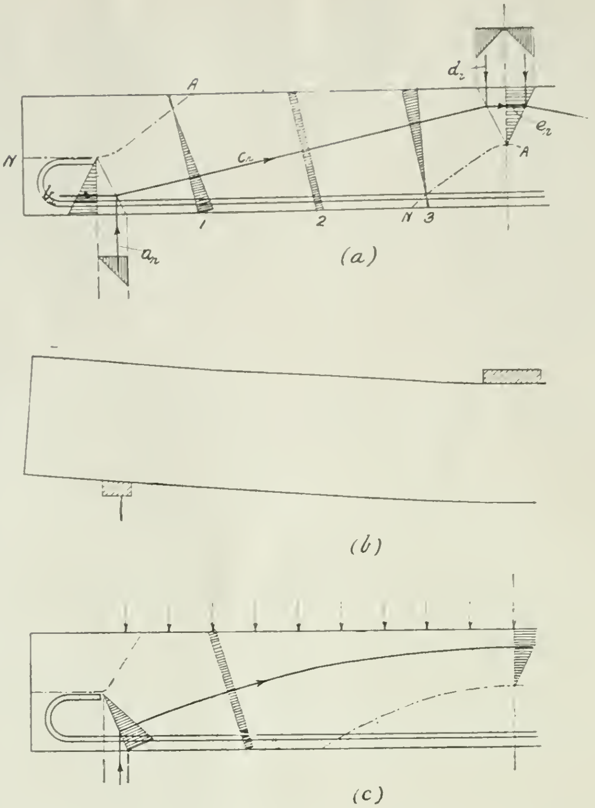


Fig. 23.
To Illustrate the Action of "Direct Inclined Compressions.

The exact conformation of the forces will, of course, depend largely on external conditions. In *Fig.* 23 (*a*) it has been attempted to show the forces produced when the stress on the support varies from a maximum at the inside edge to zero at the outer edge, as might occur owing to the deflection of the beam, as shown in *Fig.* 23 (*b*). The compression from the hook is taken to vary from a maximum at the lower surface to zero about half-way up the beam, the compression at mid-span is taken to vary from maximum at the top to zero at the neutral axis, while the distribution at the load is taken to be maximum at the two edges and zero at the centre, a condition which may also be approximated to as in *Fig.* 23 (*b*).

It is helpful to trace a small force a_r from the support to where it meets a force b_r from the hook, is resolved into e_r till it reaches the support, where it is again resolved into a load d_r and horizontal compression e_r.

Only the force a_r, the resultant, has been treated in this manner on the drawing.

If we consider sections 1, 2, and 3 across the resultant inclined compression and consider the stress as uniformly varying across the section, the stress distribution may be somewhat as shown.

It will then be found that the neutral axis, instead of remaining a straight line, now runs up to the top surface near the support, and reappears at the bottom surface near the load, somewhat as shown in *Fig.* 23 (*a*) and (*c*).

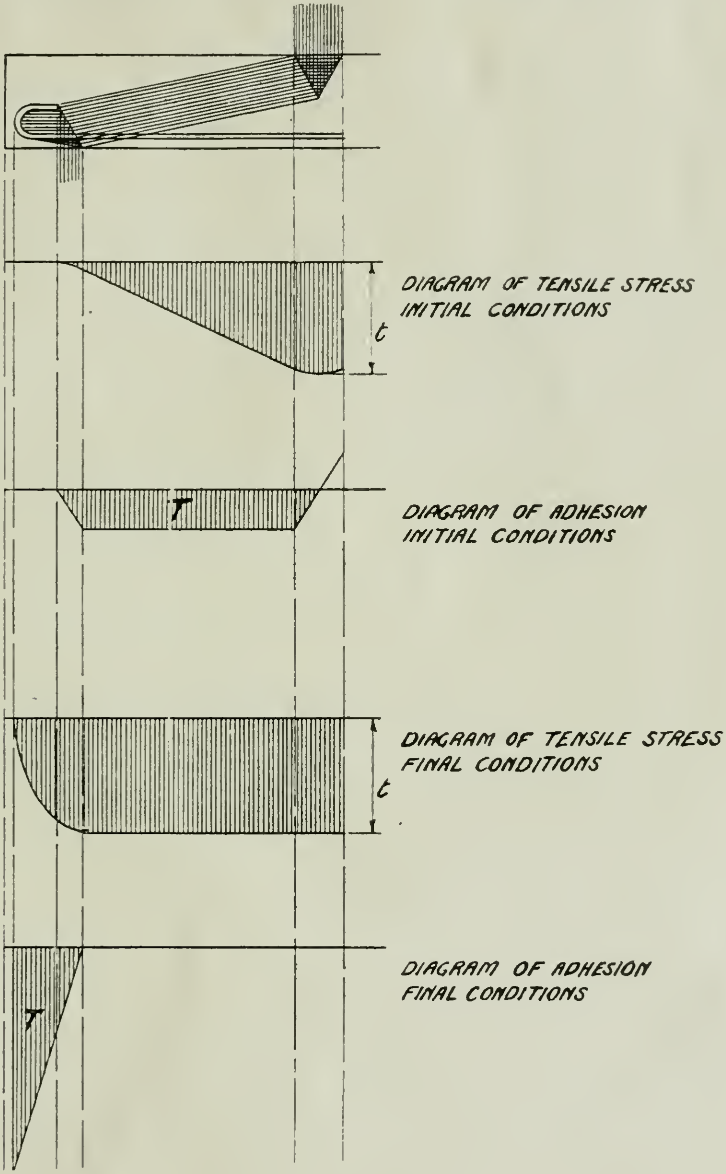


Fig. 24.
Showing the Variations in Distribution of Tensile Stress and Adhesion Stress when a Beam changes from Normal Web Conditions to Conditions of Direct Inclined Compression.

In *Fig.* 23 (*b*) a similar diagram is drawn of the case of a beam uniformly loaded, in which case the inclined compression is parabolic.

Some will have difficulty in understanding how the conditions described can exist. A common difficulty is found in the fact that the steel is in tension

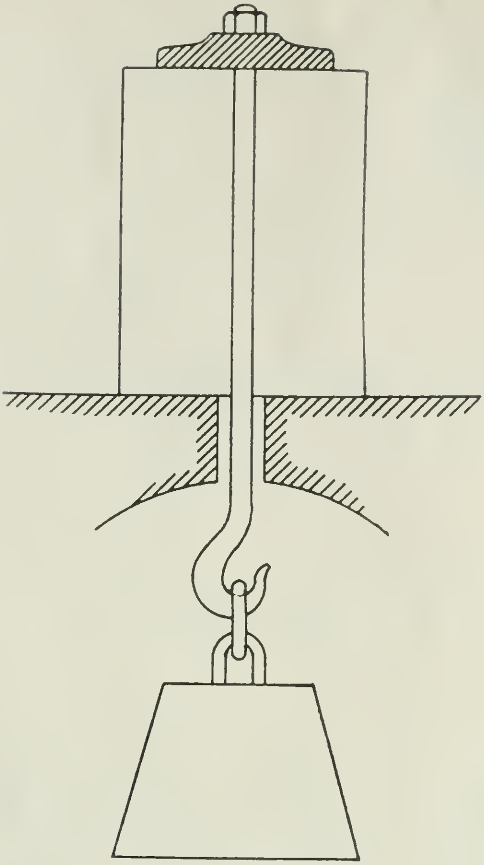


Fig. 25. To show Steel in Tension adjacent to Concrete in Compression.

throughout its length while the concrete adjacent to it is in compression, having a considerable horizontal component.

This difficulty is due to having always been taught that the stresses of steel and adjacent concrete are of the same sign and proportional to their moduli respectively—a theorem which, of course, assumes no slipping; whereas we have already explained that we realise that the steel has slipped and relies on the friction at the support and the anchorage at the hook for its tension.

Those who still find any difficulty in imagining steel in tension adjacent to concrete in compression should consider the forces produced in a block of concrete through which is a steel bar, anchored at the top with a hook or washer and supporting a load at its lower end, as in *Fig.* 25.

A second difficulty may be urged in that the condition described cannot be attained until the web concrete has failed in diagonal tension, and that it is not desirable to use in practice beams in which cracks occur. The answer to this is that the cracks are so fine that at working loads they cannot, as a rule, be detected by the eye, and that they are unobjectionable since the tensile strength of the concrete is no longer depended on. It must be remembered, too, that exactly similar cracks are always formed in the concrete before the moment of resistance is attained, stressing the steel to 16,000 lb., and no designer of experience will be found to argue that these latter cracks are dangerous.

It is interesting to note in passing that there is no difficulty in making the conditions described consistent with the usual assumption that plane sections shall remain plane after bending, provided the sections are taken at right angles to the resultant compression, though the writer would not consider it a serious criticism if this assumption had to be discarded. Karl Pearson has already shown for dams that engineers are not consistent in this matter, and that though they start off with this assumption in respect of certain planes under consideration, if the shearing and other resultant stresses are calculated, it will be found that the results of their calculations prove other planes to be unplane after bending.

We will now consider the maximum shear which can be resisted by such a system, from the point of view of its use in practical design.

The conditions to be satisfied are evidently as follows :—

(1) Steel must not be overstressed.
(2) Concrete must be overstressed.
(3) No slipping must occur at the end.

(4) The system of internal forces must at every point equilibriate the external forces.

(5) Plane sections shall remain plane after bending

As regards the first, no difficulty will be found in seeing that it is complied with.

As regards the third, an efficient hook or other fastening is obviously essential to the system. This will be considered later.

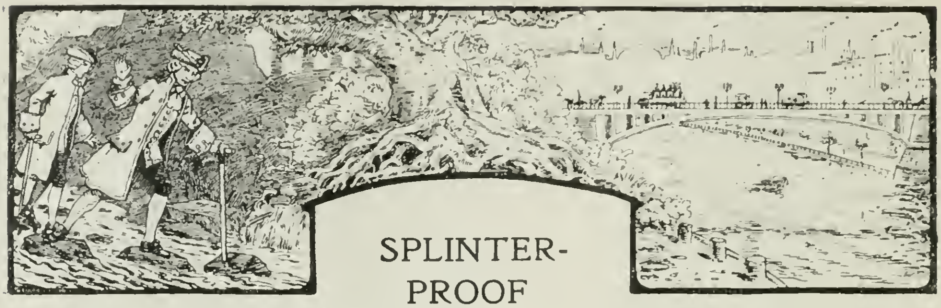
As regards the fourth, it should be noted that if the tension in the bottom member is constant from end to end, the horizontal component of the compression must also in pure beams be equal from end to end, since the total horizontal forces must balance.

If now we draw the line of the resultant compression within the material of the beam, and to such a scale and shape that the vertical distance between the centres of compression and tension represents the bending moment at that section—that is, make the shape of the compression a bending moment diagram to a certain scale—we have made the internal moments equate the external moments, and it will be found that the vertical component of the inclined compression exactly balances the external shear.

We have then completely complied with the fourth condition, and except near the hook at the ends there is no real shearing stress in the true sense on the concrete at all, but simply pure compression.

As regards the fifth, the planes will be taken at right angles to the principal stress, and the law is not necessarily complied with on all other planes.

(To be continued.)



SPLINTER-PROOF SHELTERS IN THE FIELD.

In an article which appeared some time ago in "Beton und Eisen," Dr. F. von Emperger gave the following particulars.—ED.

The necessity of splinter-proof shelters has been abundantly shown in the present war. Actually shell-proof structures are not referred to; these have been made impossible by modern artillery, and heavy roofs or domes are far more dangerous to the occupants than those of lighter construction. What is required is a structure which will resist shrapnel, and will not collapse completely when struck by a single shell, as happens with dwelling-houses, and especially with churches. The structure is thus intended to be habitable and to afford such security as is possible within the zone of fire. *Fig.* 1 gives a general section of such a structure, intended to be placed in a well-drained, shallow trench.

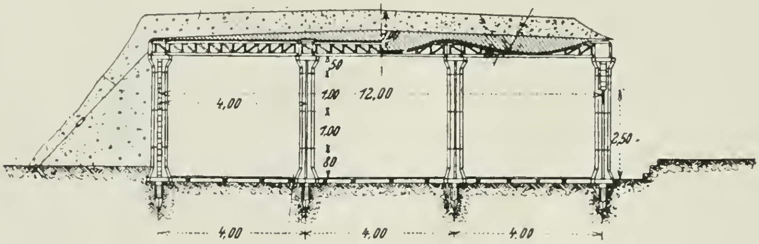
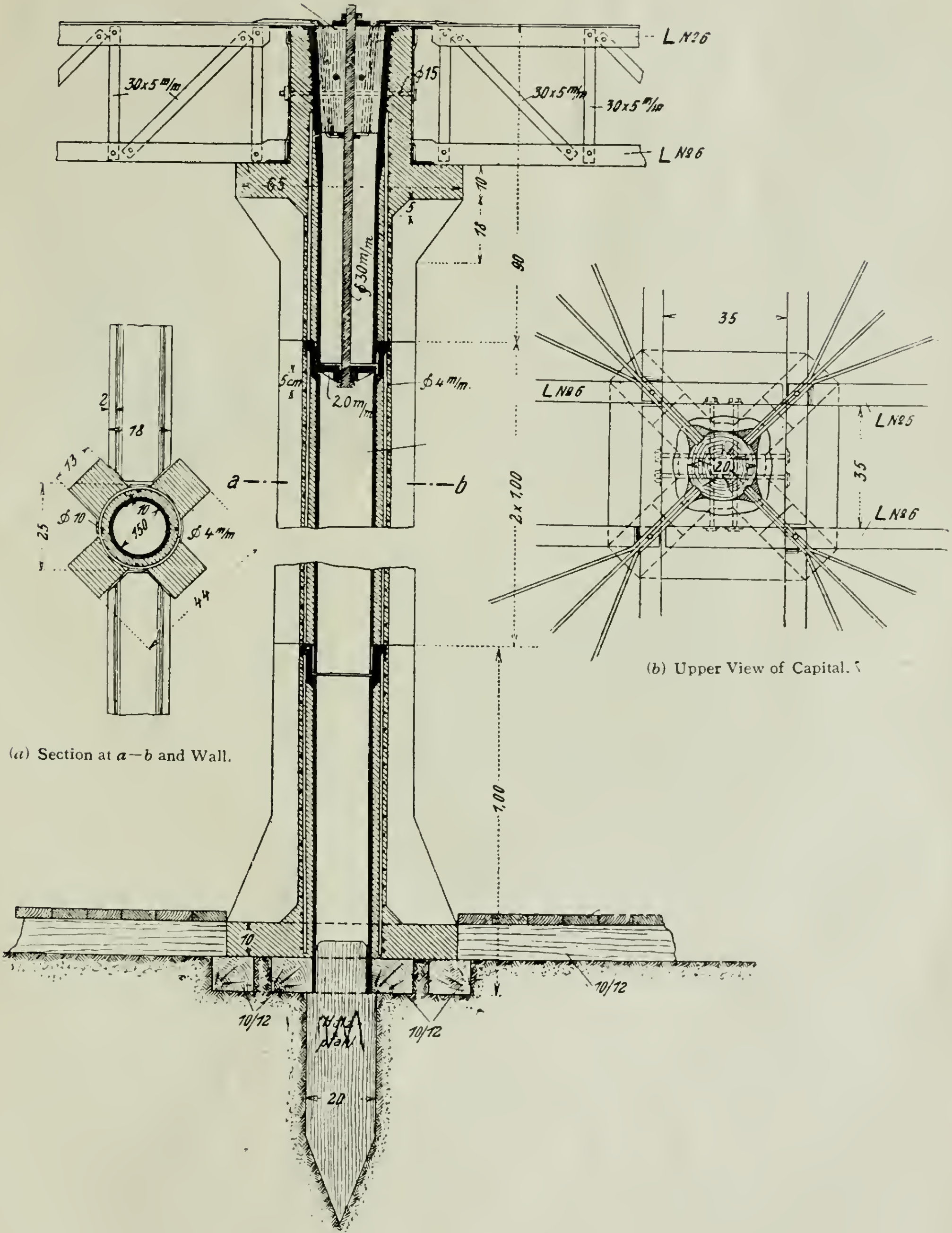


Fig. 1. • Section *a—b*.
Splinter-Proof Shelters in the Field.

Columns.—Short wooden piles are driven into the ground 4 metres apart, and a trestle erected, and the column units, in number corresponding with the height required, set in place. These units are lengths of cast-iron piping, as shown in *Fig.* 3. Each unit has four strips of wood attached, and carries 4 mm. wire as spiral reinforcement in the concrete. Each column has a specially formed capital to support the roof.

Roofing.—This is constructed with netting supported from an iron framing. *Fig.* 2 shows the general arrangement, and the details are seen in *Fig.* 2*b.*



(*a*) Section at *a*—*b* and Wall.

(*b*) Upper View of Capital.

Fig. 2. Section.
SPLINTER-PROOF SHELTERS IN THE FIELD.

From each capital three wires start in the direction of a diagonal, and are fixed and connected as shown in the figures. These support the wire netting, on which a layer of tarred felt is laid. Sand or dried earth is placed above this, with a final layer of tarred felt to exclude water. A layer of 75 cm. thickness is assumed.

Walls.—Both external walls and partitions are best constructed of concrete slabs. *Fig.* 1 shows the most unfavourable condition, the structure being on a level. It is generally possible to take advantage of inequalities of the ground, railway embankments, etc.

Some excellent examples of concrete construction have been seen in the present war. Both the British and French have made great use of concrete in their trenches. The method of construction here proposed, which utilises only materials in common use, is eminently suitable for refuges and shelters for men and horses, for stores, observation posts, and staff quarters, as well as for hospitals, as the latter are now no longer spared. The taking down and re-erection are very simple. For an arc of 12 × 100 = 1,200 sq. metres, sufficient for a company, the materials required include 416 column units, 72 roofing girder frames with wires, netting, felt and wood for flooring, the total weight being 150 tons.

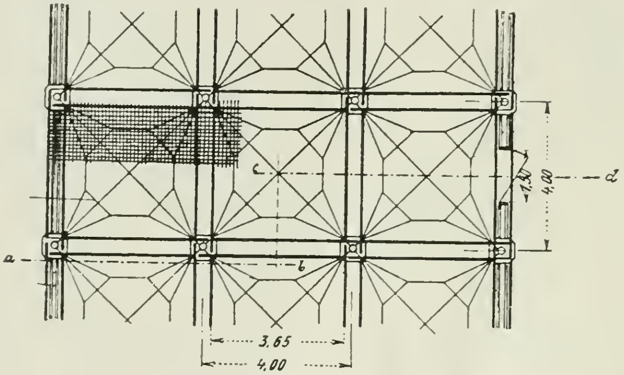
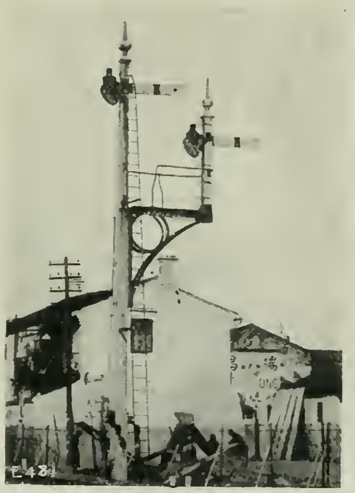


Fig. 3. View from above without earth.
Splinter-Proof Shelters in the Field.



A Concrete Bracket Signal.

CONCRETE ARTICLES ON CHINESE RAILWAYS.

For the particulars and illustrations in the following article we are indebted to our correspondent, Mr. I. Tuxford, Maintenance Engineer on the Shanghai-Nanking Railway.—ED.

Our readers will recall an article published in our January number on the varied uses which can be made of concrete on our railways, such as slabs, posts, culverts, drinking troughs, pipes, etc., etc.

A correspondent has now sent us some interesting illustrations of articles in use on one of the Chinese Government railways (the Shanghai-Nanking line) which bear testimony to the enterprise of the Chinese railway engineers.

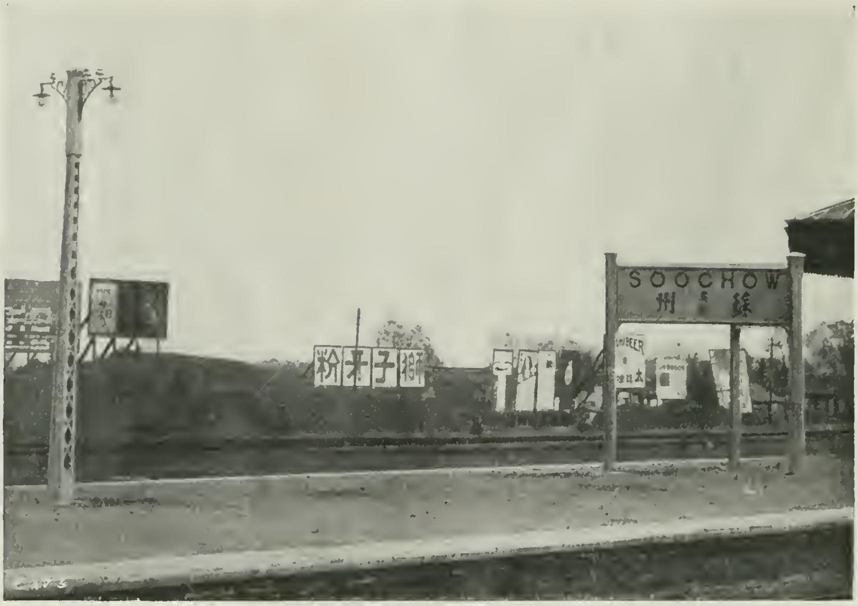
The Shanghai-Nanking Railway commenced the adoption of concrete articles some four years ago, and with such signal success that not only has all possible timber been replaced with concrete, but the Shanghai-Nanking line has also supplied concrete articles to the Shanghai-Hangchow Railway and the junction line connecting the two.

Among the articles specially mentioned are signal posts, fence posts, platform blocks, pipes, etc.

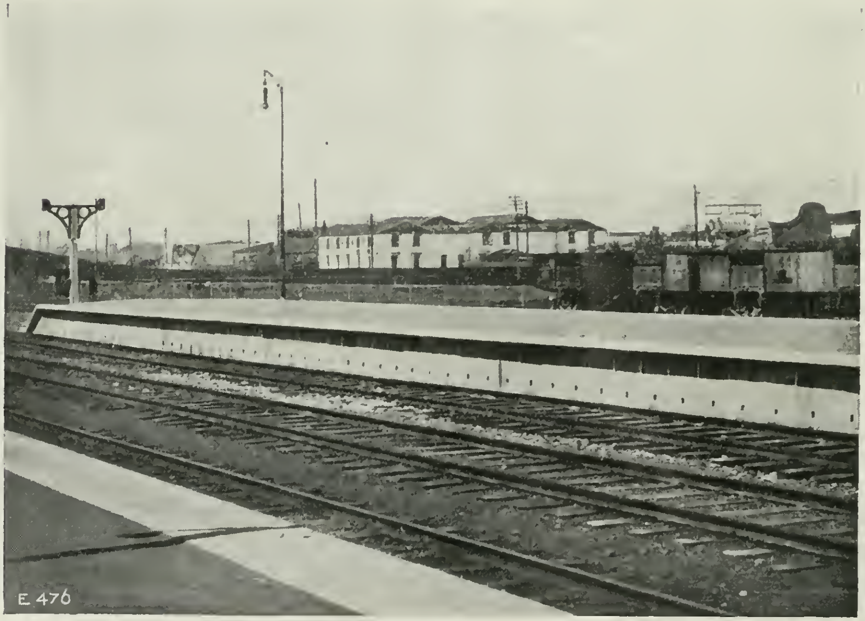
Our correspondent points out that experiments were first made on the Shanghai-Nanking Railway with concrete fence posts. These proved so successful that a trial was at once made of signal posts, signal wire pegs, platform blocks, culverts, pipes, lamp posts, station name boards, and numerous other articles which are needed in connection with railways.

These all proved to be very economical in construction, and the cost of the signal posts, name boards, etc., compares very favourably with the cost of the same in timber.

Among our illustrations our readers will observe a reinforced concrete coal stage, which will probably be of interest to many.

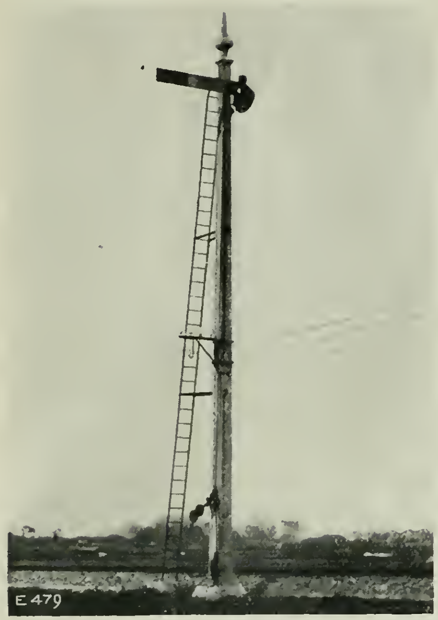


Electric Light Post and Station Name Board in Reinforced Concrete.

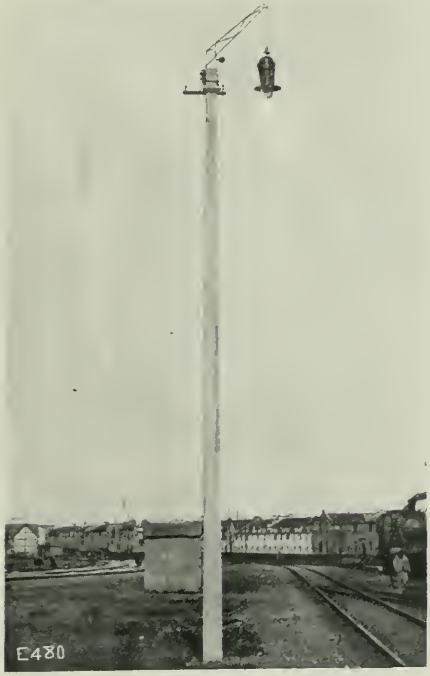


Concrete Platform Wall Blocks in position.

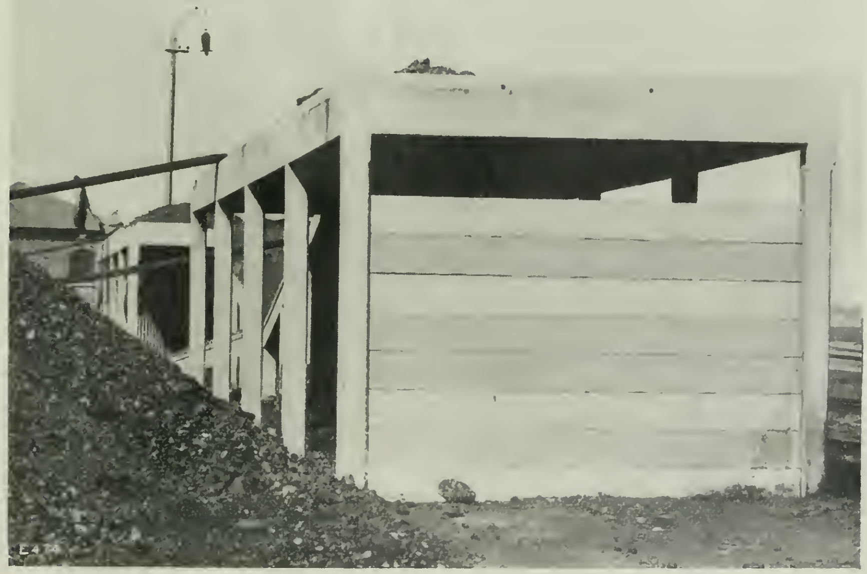
Concrete Articles on Chinese Railways.



Outer Home Signal.



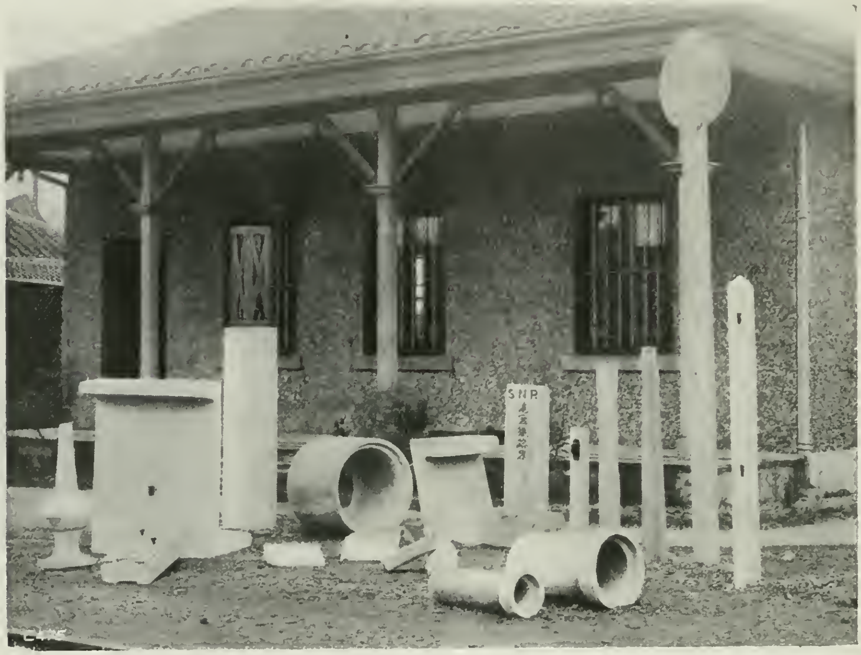
Concrete Lamp Post.



Reinforced Concrete Coal Stage.

Concrete Articles on Chinese Railways.

The uprights are 8 in. by 8 in. posts, grooved down the sides, and the sides of the stage are composed of concrete slabs which fit into the grooves. The reinforcement to the floor of the stage is of Expanded Metal, supplied by the Expanded Metal Co., Ltd.

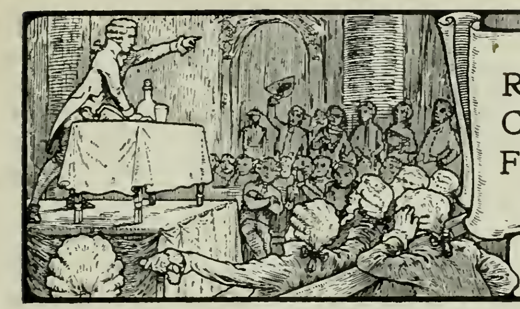


The articles here shown are, looking from left to right:—Top of signal post; block for platform wall; ashpit coping (under rail); concrete base for timber post; tiles; sewer pipe; block for platform walls of small stations; half round gutters; boundary stone; drain pipes; signal wire peg; wire fence posts; disc post: post for station fencing.

Concrete Articles on Chinese Railways.

The cost of maintenance of these coal stages is practically nothing, whereas in the old timber stages the maintenance charges were high.

Concrete signal posts and station name boards are also very economical from a maintenance point of view, the only painting which is required being the signal arm of the posts and the letters on the name boards.



RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

"*JOURNAL OF AGRICULTURAL RESEARCH.*"

APPARATUS FOR MEASURING THE WEAR OF CONCRETE ROADS.

By A. T. GOLDBECK,

Engineer of Tests, Office of Public Roads and Rural Engineering.

The following is a reprint taken from the "Journal of Agricultural Research," Washington, D.C.

Many miles of concrete roads have been built during the past few years, and the methods employed in their construction are rapidly becoming standardised. The concrete mixture is now made comparatively rich, and in general the aggregates are selected with as much care as present knowledge of these materials permits. Even yet, however, it is doubtful whether the right mixture is being used for the purpose : Whether it is too rich for economy or whether it should be made still richer. It is questionable what kinds of coarse aggregates give the most economical results : Whether they should be composed of hard, tough fragments of trap rock or of softer, more friable pieces of limestone of approximately the same degree of hardness as the mortar in which they are embedded ; whether angular fragments of crushed stone should be used or whether round pieces of gravel are equally satisfactory. Definite knowledge on these points based on scientific information seems to be lacking.

The ideal concrete road should wear uniformly and slowly. When due care is exercised in construction and the necessary precautions are taken in maintenance, uniformity of wear may to a large extent be controlled. But little is known about the rate of wear of concrete roads having various aggregates and carrying different kinds of traffic. General observation indicates that some roads with particular kinds of aggregates are wearing more slowly than others containing different coarse aggregates, even though the traffic conditions are nearly alike. We have, however, no definite idea of the amount of wear in these different roads. There must come a time in the life of every concrete road when, notwithstanding careful maintenance through crack protection and patching, its thickness will approach the minimum, making imperative the expenditure of a considerable amount of money for a new wearing surface to replace that gradually worn away by traffic. Every fractional part of an inch decrease in thickness therefore represents a very definite depreciation in the value of the pavement. Money cannot be expended intelligently on various aggregates mixed with cement in different proportions for road construction without accurate knowledge of one of the most important factors governing the expenditure—namely, the probable rate of depreciation of the road as determined by actual wear.

This consideration has led the Office of Public Roads and Rural Engineering to attempt to gain definite knowledge of the wear of concrete roads carrying various kinds of traffic, and a special instrument has been designed by the writer and built in this office for that purpose. Several methods of taking autographic records of the cross section of the road were considered, but were discarded in favour of the simpler and more portable form of instrument finally constructed.

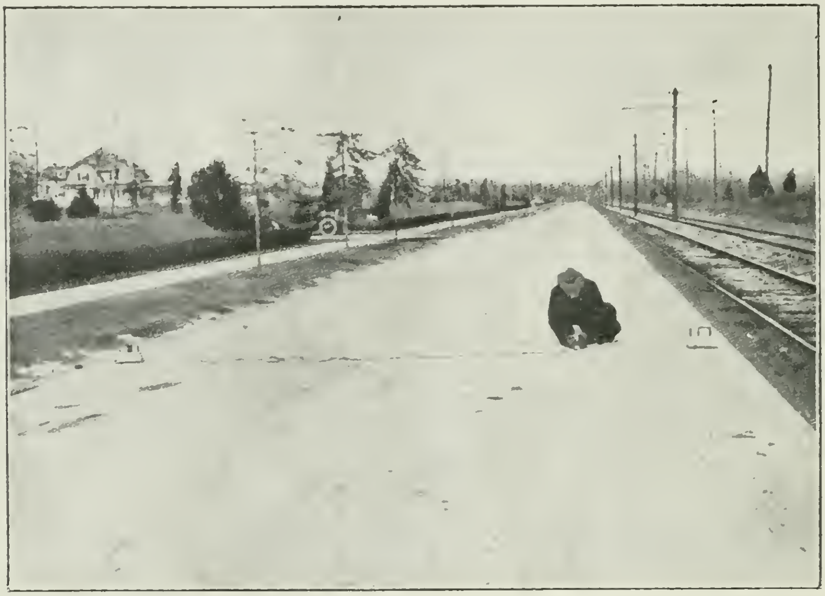


Fig. 1.

Essentially, this instrument consists of a fine wire stretched tightly across the road at a constant height, together with an inside micrometer for measuring the distance from the road surface to the wire. Measurements taken 1 ft. apart across the road permit the plotting of its cross section, and if these measurements are repeated at long intervals the change of cross section or the decrease in the thickness of the road will be revealed.

The accompanying illustrations show the instrument in detail and its method of application on the road. If the photograph, *Fig.* 1, and the diagram 2 are first referred to, the component parts of the apparatus may be seen very plainly.

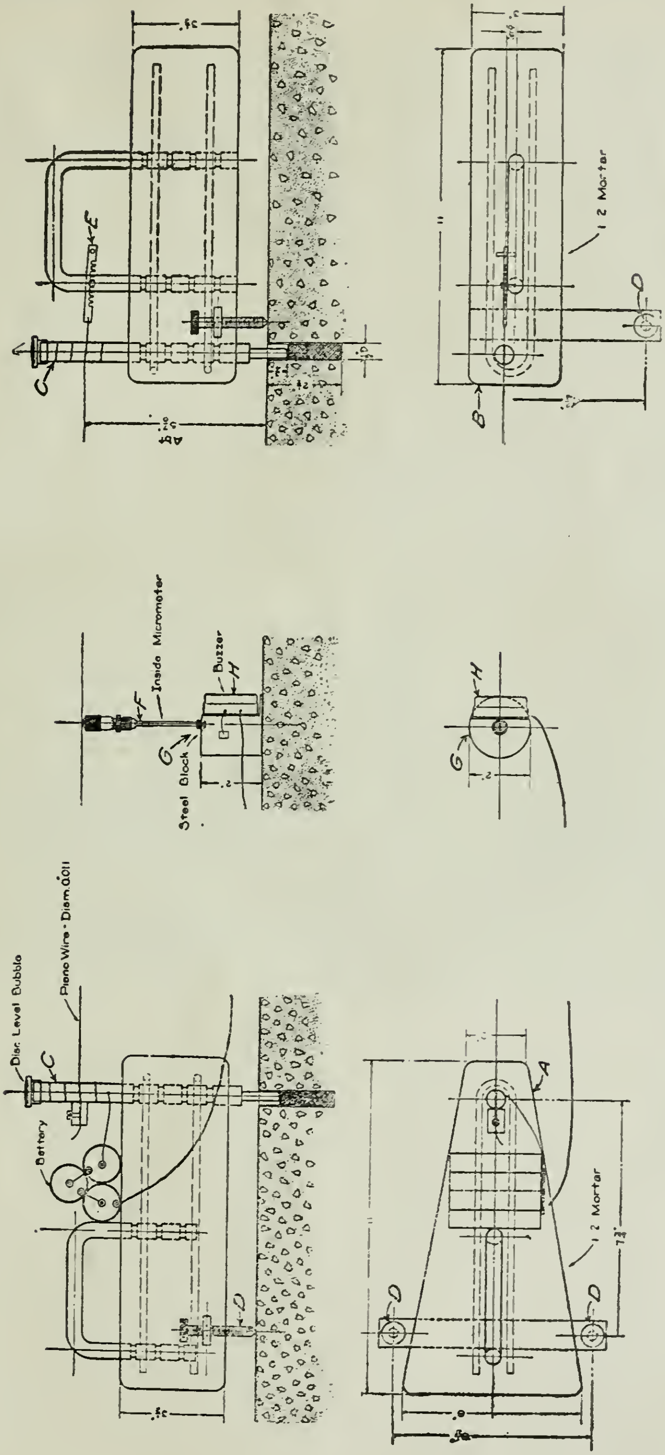


Fig. 2. Details of instrument for measuring the wear of roads: *A*, Heavy mortar block; *B*, Light mortar block; *C*, Steel rod; *D*, Level adjusting screws; *E*, Adjusting rack; *F*, Inside micrometer; *G*, Steel bearing block; *H*, Electric buzzer.

Pieces *A* and *B* are made of cement mortar and have embedded in them steel rods, *C*, drilled with holes slightly inclined with the horizontal. A fine piano wire about 0·01 of an inch in diameter is passed through these holes and is stretched across the road from block *A* to block *B*. The tops of these rods are each provided with a disc-level bubble, so that when placed in position in the road the rods may be adjusted to a vertical position. Block *A*, which is heavier than block *B*, is provided with two adjusting screws, *D*, for adjusting rod *C* to the vertical. Block *B* rests on two points only, one the lower end of rod *C* and the other the end of adjusting screw *D*. Constant tension is produced in the wire by the weight of block *B*, which is pivoted about the bottom of rod *C* and is adjusted to a horizontal position by means of rack *E*, provided at the end of the wire. As the weight of block *B* is constant, the tension in the wire, and consequently the amount of sag for like spans, must remain the same. A very definite and fixed datum is thus provided, which should remain constant from year to year and which is very easily established by merely placing the end blocks of the apparatus in their proper position on the road.

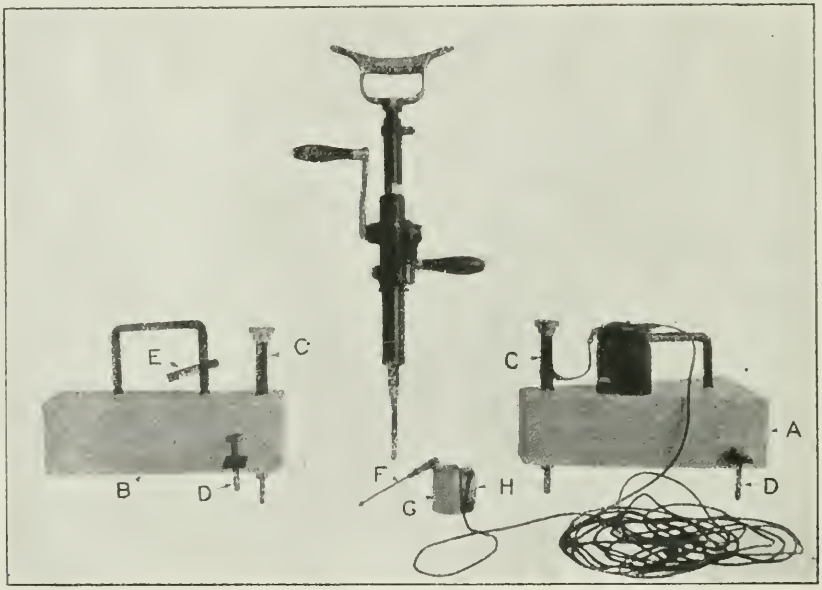


FIG. 3.

The bottoms of rods *C* are spherical in shape, and when in use on concrete roads, they rest on the flat tops of bronze plugs cemented in the road surface. These plugs are $\frac{1}{2}$ in. in diameter and are $1\frac{3}{4}$ in. long. They are set $\frac{3}{4}$ in. below the surface, and their tops are protected by means of a brass pipe plugged with a bituminous-sand mixture during the long intervals between readings.

In obtaining the wear measurements a chalk line is first snapped across the road between the bronze plugs, and the points at which it is purposed to take readings are marked on this line. At these points a steel block, *G*, 2 in. in diameter, is placed, in order to avoid measuring the small local inequalities in the road surface. In the top of this block a flat-bottomed cylindrical recess is made, and an ordinary inside micrometer is held in the recess, while its upper end is adjusted to contact with the steel wire stretched across the road. An electric buzzer, *H*, is mounted on the side of this block, and when contact is made between the micrometer and the wire an electric circuit is completed through the buzzer. With this instrument readings for wear may be taken to the nearest 0·001 in., although this degree of accuracy will not be necessary.

Holes in the road in which the bronze plugs are set are drilled by means of a special hand-operated drill press carrying a star drill.

In *Fig.* 3 the method of mounting the apparatus in the road and its manipulation are plainly shown. On the left is the heavier end block carrying the batteries, and on the right is the lighter block the weight of which supplies constant tension to the fine steel wire, part of which is seen in front of the operator. The cord extending on the road surface from the heavier block to the small steel block carrying the micrometer is one of the leads from the battery to the electric buzzer.

Placing the buzzer in this position near the operator obviously is advantageous, especially when the instrument is to be used amidst the distracting noises of traffic. The end blocks are set as near to the sides of the road as practicable, in order to permit measurements being taken across almost the entire width of the road. Should longitudinal cracks develop through the sections measured, the readings so taken will be rendered useless; and in order to eliminate this difficulty, sufficient plugs must be set to permit obtaining readings at uncracked sections.

Wear measurements of this kind taken of the actual road surface should prove of great future value if the traffic conditions and the physical characteristics of the concrete materials likewise are known, and should help to decide present moot questions regarding concrete roads and road materials. Not only may concrete surfaces be measured for wear in this manner, but the wear or vertical movement of other kinds of road surfaces may likewise be determined by the use of this instrument.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

COAL HOPPERS AND WASHING BUNKERS AT GLASSHOUGHTON, YORKS.

In our March issue we stated that reinforced concrete was becoming more and more popular in the North of England, and the present article deals with part of a large plant which has been lately erected for the Yorkshire Coking and Chemical Company, Ltd.

These buildings are used for coal washing and a bye-product plant, and there is no doubt that when this war is over and the commercial war begins we shall see the industries relying on the bye-products of various materials greatly developed, and in the buildings and plants for such work reinforced concrete will play a great and ever-increasing part.

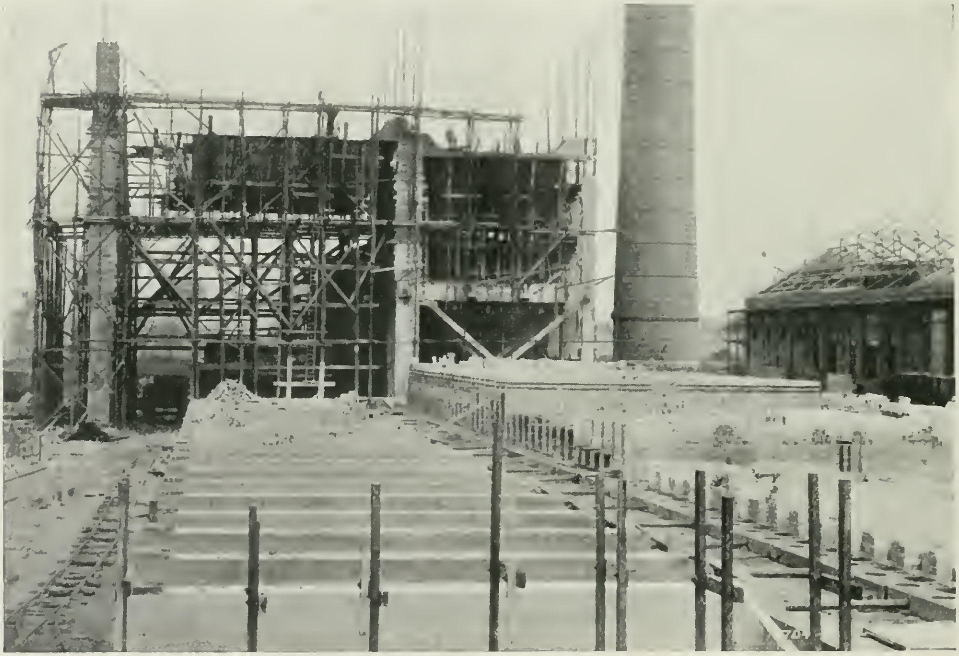


Fig. 1. Building in course of construction.
Coal Hoppers and Washing Bunkers at Glasshoughton, Yorks.

As will be seen from the plan (*Fig.* 2), the washing building consists of a rectangular structure 186 ft. long and 34 ft. wide, with a projecting bay at one end to accommodate a large 60-ton shale hopper. At the side of the building is the elevator pit, which is sunk in the ground, so that trucks can tip direct into it, and from which the coal is raised.

The height of the building is 65 ft. from ground floor to the eaves, and consists

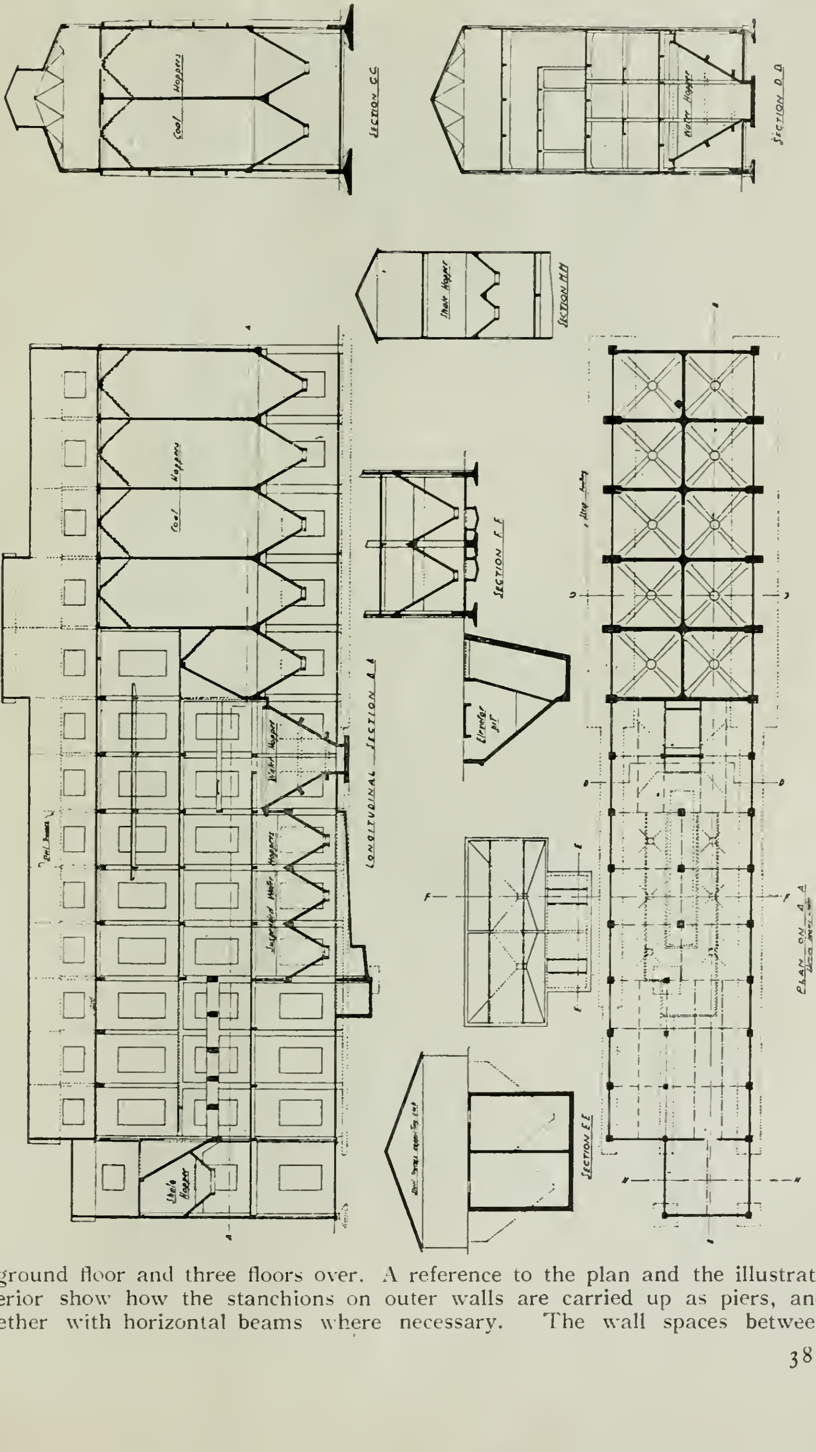


Fig. 2. Plan.
Coal Hoppers and Washing Bunkers at Glasshoughton, Yorks.

of ground floor and three floors over. A reference to the plan and the illustration of exterior show how the stanchions on outer walls are carried up as piers, and tied together with horizontal beams where necessary. The wall spaces between are filled in with reinforced concrete, with openings left for iron sashes, and in many places these walls are but 4 in. thick.

The ground floor itself is of reinforced concrete, and in it are formed two pits, one for the pump foundations and the other to receive the water from the water hoppers, of which there are six, suspended from the first floor level. Between these

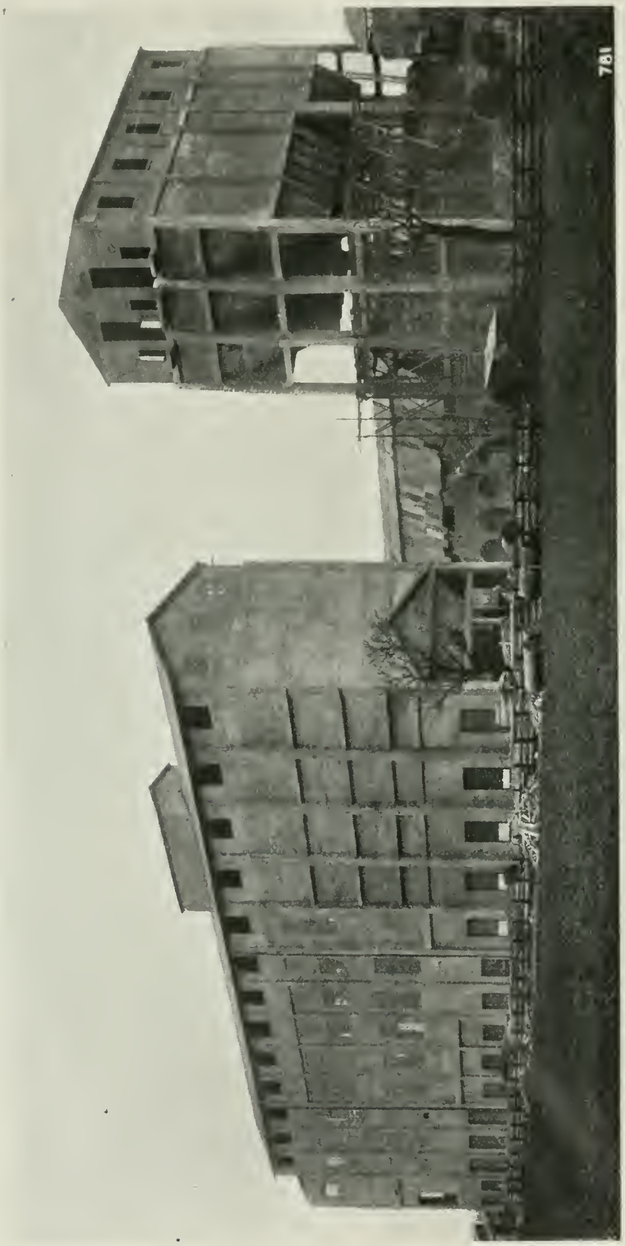


Fig. 3. General View.
Coal Hoppers and Washing Bunkers at Glasshoughton, Yorks.

water tanks and the coal hoppers is a large dredger sump, from which a conveyor lifts the coal to the washed coal hoppers, of which there are ten, eight of them with a capacity of about 200 tons each and two smaller ones of 90 tons each.

A row of stanchions runs from end to end of the building, and these are carried up to support the first and second floors, but the top floor is carried on beams running right across the building. These stanchions also support several galleries and machine beds, and throughout the building reinforced concrete has been used wherever possible. The roof consists of a 2½ in. reinforced concrete slab resting on purlins carried by steel trusses.

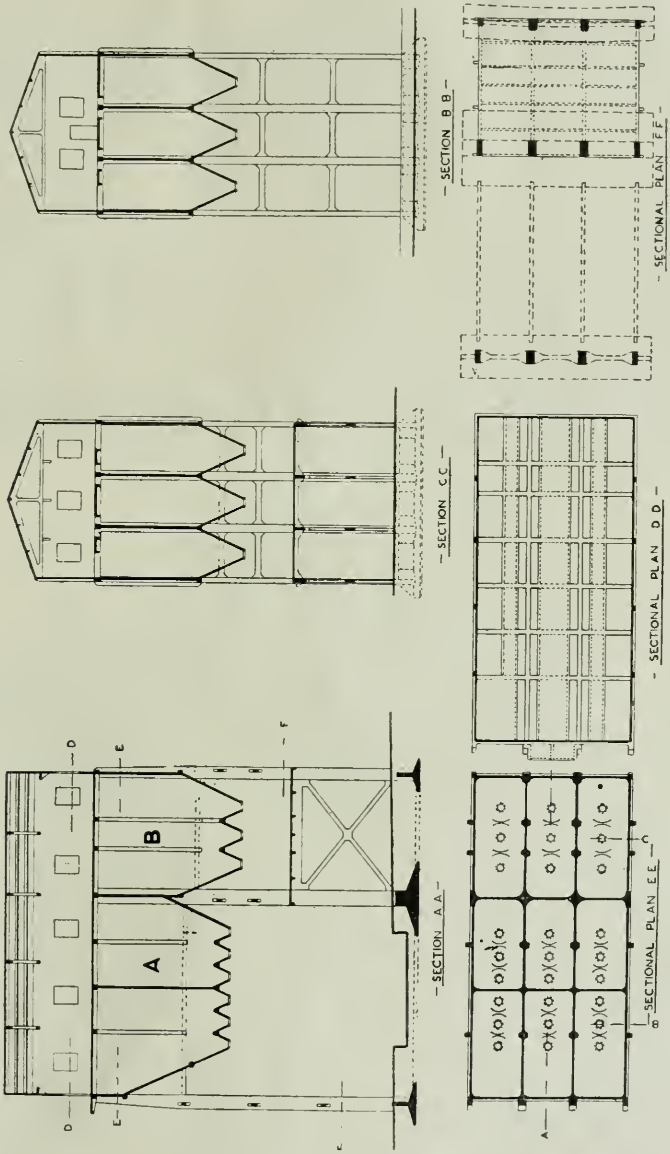


Fig. 4. Details of Coal Hoppers.
Coal-Hoppers and Washing Bunkers at Glasshoughton, Yorks.

In close proximity to the washing building a large coal store has been erected, with a capacity of 1,880 tons of small washed coal. This building is 87 ft. long and

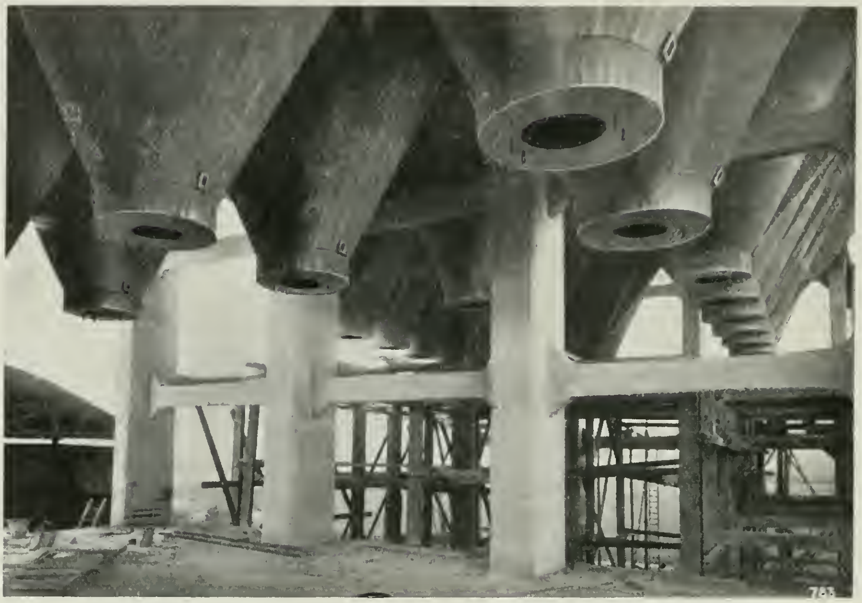


Fig. 5. View of Conical Hopper Mouths.

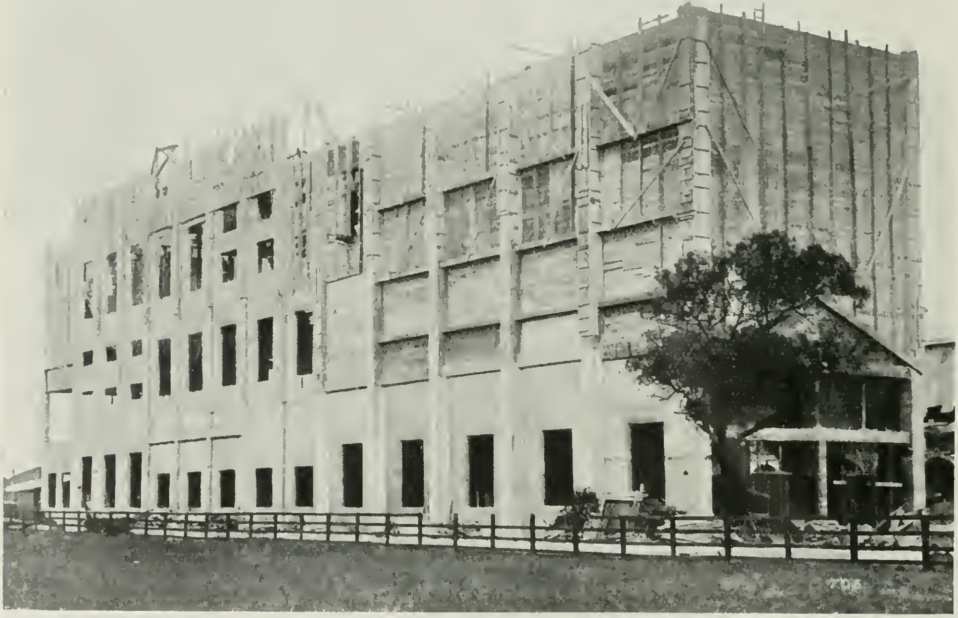


Fig. 6. Building in course of Construction.
Coal Hoppers and Washing Bunkers at classhoughton, Yorks.

41 ft. wide, and except for window frames, which are of iron, and the necessary fittings, it is entirely constructed of reinforced concrete. As will be seen from the sections, *Fig.* 4, the hoppers are raised a good distance from the ground, and thus very careful designing was needed for the columns to withstand the stresses that are put upon them. These stanchions are of various sizes up to 4 ft. by 2 ft., and are tied together by beams and cross braces. The sides of the bunkers have also been designed as beams, and are greatly strengthened by projecting vertical beam stiffeners. (See sections on *Fig* 4.)

Among the points worthy of study are the large footings, which are really T beams designed to spread the weight over a large area; also the conical hopper mouths, which are circular in plan in lieu of the usual square form.

The whole of the work has been carried out to the designs of the Koppers Coke Oven and Bye-Products Company, of Sheffield. Messrs. J. W. and G. Sugden, of Bradford, were the contractors, and the Indented Bar Company, of Queen Anne's Chambers, Westminster, were the specialists for the reinforced concrete work.

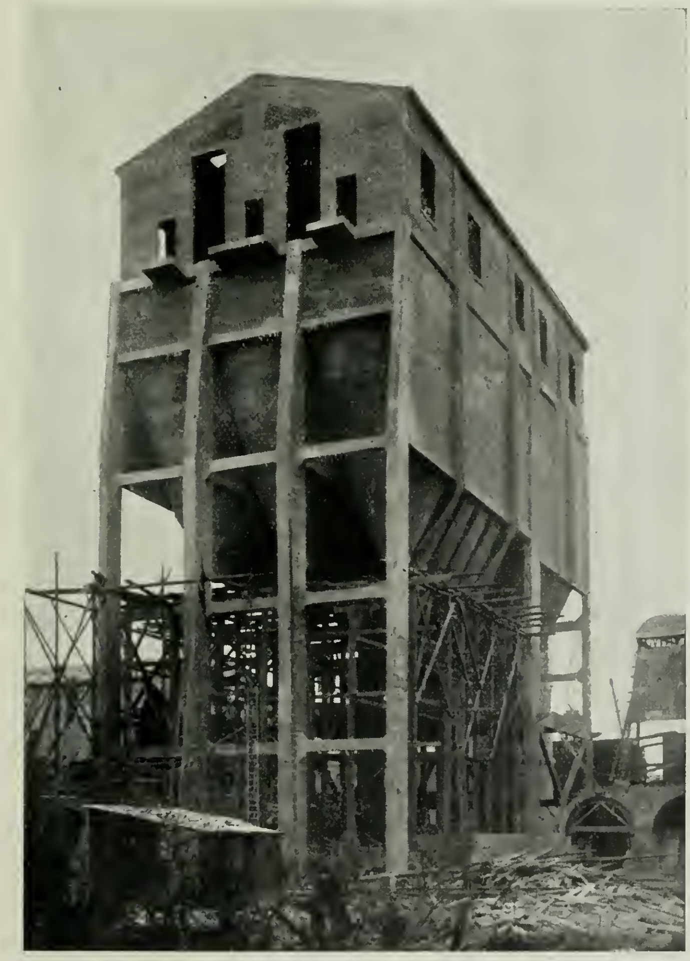
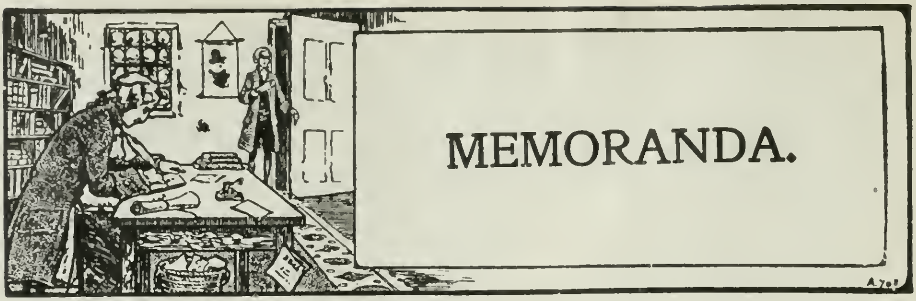


Fig. 7. View of Coal Hopper.
COAL HOPPERS AND WASHING BUNKERS AT GLASSHOUGHTON, YORKS.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Concrete Slabs for Military Camp.—In our June number we published an illustrated article under this title, but inadvertently we omitted to state that Messrs. Harper Bros. and Co., the consulting engineers, were acting on behalf of the War Office for the design and supervision of this work.

To give some idea of the extent of this scheme with which they had to deal, the following details may be of interest: The work covers an area of two thousand acres and a length of three and a-half miles, and electric lighting, sewage, water supply, and the construction of 150 miles of roads and paths are included in this undertaking.

The total cost of the works will amount to over £1,000,000, of which the camp construction will absorb about one-half, the contracts for the Winget hut constructions, carried out by Messrs. Boot and Sons, Ltd., of Sheffield, and Messrs. Sykes and Co., of London, amounting to £150,000 in each case.

Fishguard Harbour Works.—We have from time to time made short references to the Fishguard Harbour extension works. In an article in the *Times Engineering Supplement*, the following particulars have been published in regard to this important work, to which we hope to come back at a later date:—

" The extension of the northern breakwater to the designed length of 3,000 ft. has proved a difficult undertaking. Owing to the rough seas to which the outer face is exposed, a special design has had to be adopted. The foot of the wall is built on a 6 to 1 slope of selected stone for the greater part of its length, and above this is a berm of heavy rubble or concrete blocks 10 to 12 tons in weight, the whole being converted into a solid mass by grouting with Portland cement concrete. The upper part of the wall is composed of 40-ton concrete blocks laid pell-mell by a Titan crane, this section fulfilling the purpose of a wave-breaker. Behind it is the apron and the parapet carried to a height of 30 ft. above sea level. The breakwater has a concrete core, and the whole structure forms a huge mole, having an average width of 300 ft. at its base and 60 ft. at the top.

" The concrete blocks are being made by the contractors, Messrs. Topham, Jones and Railton, in a block house which has been erected on a portion of the reclaimed foreshore at the Goodwick end of the harbour."

The Use of Concrete on the Battlefield.—It would appear from accounts which have appeared in the daily Press that concrete has been extensively used for defence works. In *The Times*, for example, it is stated in the *communiqué* from Petrograd that in one sector alone of the enemy's position which the Russians carried they took, in addition to 21 searchlights, two supply trains, field kitchens, machine guns, etc., 193 tons of barbed wire, 1,000 concrete girders, and 7,000,000 concrete cubes, besides coal and other war materials.

Road Work in Shanghai.—Cement-Concrete Wearing Surfaces.—In his report for the year 1915, Mr. Charles H. Godfrey, M.Inst.C.E., Municipal Engineer of Shanghai, refers to a departure which he has made in permanent paving by the construction of a road in cement-concrete without the addition of wood blocks or other material as a wearing surface. An attempt was made to provide a thin bituminous carpet, but it was not successful, owing to imperfect adhesion to the concrete. Mr. Godfrey remarks that local experience in this respect, as well as in other details of the work, is identical with that of American cities of which information has since been received. He adds that there is every indication that concrete roads will prove satisfactory and suitable for many of the narrow and congested roads of the central district—at present macadamised—at a cost considerably lower than that of roads where concrete has served as a foundation for wood and other blocks.

Tar-painting on the outlying roads of Shanghai has formed an important part of road maintenance work, and asphaltum macadam has been laid in some of the roads which take heavy traffic, with results which have so far been very satisfactory.

The mileage of roads under the control of the Municipal Council is about 120 miles, of which 74½ miles are macadamised, 20 miles paved, and 25½ miles unmetalled. Of 104½ miles of footways 89 miles are paved.—*Surveyor.*

New Office Building, Glasgow.—A new office building has recently been completed for Messrs. Alex. Stephens and Sons, Ltd., shipbuilders and engineers. It is a three-storied building 159 ft. 6 in. by 50 ft. 10 in. The entire superstructure is of reinforced concrete, and the building is an excellent example of the way in which reinforced concrete can be used architecturally. The architect was Mr. F. G. Orr, and the reinforced concrete design was placed in the hands of the Considère Construction Co. The general contractors were Messrs. Melville, Dundas and Whitson.

Concrete and Reinforced Concrete at the Maldens and Coombe Sewage Works.—In a paper recently read before the Lower Thames Valley District Surveyors' Association, Mr. R. H. Jeffs, A.M.Inst.C.E., gave an interesting account of the extensions carried out at the above works in recent years. Amongst the works carried out was the increase in depth of one of the sedimentation tanks to 8 ft. by raising the walls, and a new percolating filter, 80 ft. diameter, installed. The new work to the tank was carried out in reinforced concrete, also new channels adjoining the engine-house were constructed, and a recording apparatus installed. The clinker in three contact-beds was washed and renewed, and other improvements made.

The whole of the work was carried out departmentally, and cost £1,230, the details being: Sedimentation tank, £191; percolating filter, £585; improvements to contact beds, £454. This was done in 1910, and the additions were opened in February, 1911. The beneficial effect of these works was at once apparent, but still further works were felt to be necessary to put the Council in an entirely satisfactory position. Accordingly, in February, 1912, a further report was presented to the Council by the author, recommending additional percolating filters, humus tanks, sedimentation tanks, detritus tanks, and sludge beds. A sub-committee of the Public Health Committee was formed to consider the matter, and after very careful consideration they reported to the Council in January, 1913, adopting the author's scheme. The sanction of the Local Government Board was given in due course and tenders obtained, that of Messrs. J. May and Sons, of Ashtead, being accepted for the sum of £6,124, and a start was made in March, 1914. The works were well carried out, and a saving of £314 on the above sum was made. Simplicity has been aimed at throughout, so as to obtain the greatest amount of purification with as small an outlay as possible.

The sewage, on arrival at the works, is lifted by means of a 12-in. centrifugal pump and 8-in. centrifugal pump, and one 10-in. three-throw pump and one 12-in. pump, the motive power being obtained from a 50 h.p. Diesel oil engine, erected in November, 1913, and a 50 h.p. and 10 h.p. Tangye gas engines run on town's gas. The total lift is 40 ft. The sewage is discharged into a channel outside the engine-house and is measured over a 5-ft. weir by means of an Adams Recorder. It then flows through two detritus tanks, the combined capacity of which is 29,815 gallons. The walls of these tanks are of reinforced concrete, about 1 ft. thick.

The sewage then passes through three sedimentation tanks, 108 ft. by 31 ft. by 8 ft. deep, with a capacity of 500,000 gallons, equal to one day's dry-weather flow, or 38 gallons per head of population. The method of working is by continuous flow. The tanks are arranged for working either in series or parallel, the former, in the author's opinion, giving most satisfactory results. Sludging takes place about once a month, the sludge falling by gravitation through a 9-in. pipe to the ejector chamber and being lifted on to the sludge beds, of which there are nineteen.

The sludge from sedimentation tanks, high and low level humus tanks, and washing out of supply pipes to percolating filters is dealt with by two 25-gallon ejectors. A 6-in. rising main conveys the sludge to the beds.

On leaving the sedimentation tanks, the sewage passes into a chamber through

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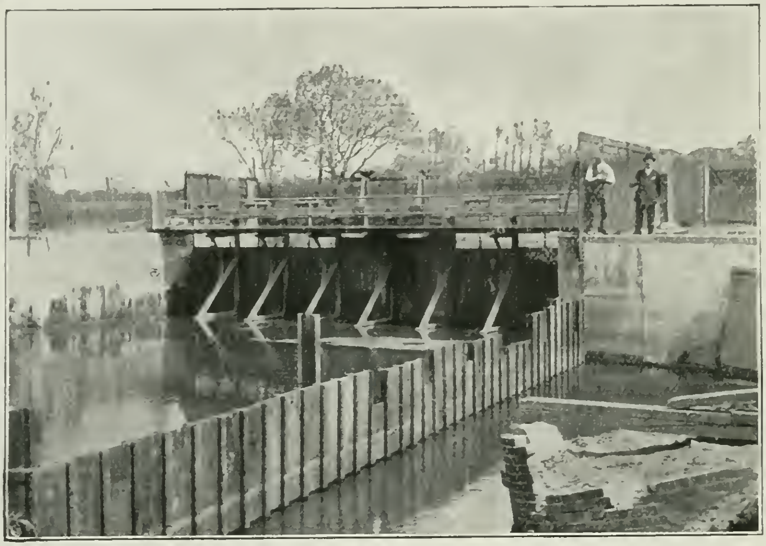

Photograph shows our 15" × 5" Universal Joist Piling in use for repairs and diversion work in connection with Flanders Weir, Chingford. Some of the piles were driven lower than others for the purpose of supporting timbers on which the gantry rested, from which the other piles were driven.

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an opening designed to admit three times the dry-weather flow, any excess above this amount passing over a weir and along a channel to the storm-water filters and irrigation area.

From the chamber above mentioned the sewage is conducted to the distributing chambers, through 24-in. concrete tubes with 18-in and 15-in. branches, and is thence passed on to six percolating filters, each 80 ft. diameter and 4 ft. 7 in. deep.

After leaving the percolating filters, the effluent passes along an open channel, 3 ft. 6 in. wide, and through two high-level humus tanks, of a capacity of 42,806 gallons, where a large amount of suspended matter is arrested. These tanks are constructed of reinforced concrete, on the same principle as the detritus tanks, and have means for disposing of the solid matters by the hydraulic head of water in the tank. Some trouble is experienced, however, with the fine grit passing away from the filters, which precipitates to the bottom and is difficult to raise through the sludge pipes. This necessitates a periodical cleaning out. Possibly, in the future it will be found advantageous to employ a portable pump for emptying the tanks.

After the effluent leaves the humus tanks it can be sent direct to the outfall, or if desired can again be treated through the contact beds.

These contact beds are now retained primarily for storm-water treatment. The cubic capacity of the four reconstructed beds is 4,462 cub. yds. excluding the two old beds.

Further improvements were made to these beds during the last extensions, and a new outlet channel formed, which has greatly assisted in the aëration of the effluent. The effluent from the contact beds is treated through two low-lying humus tanks of identical design and construction to the high level ones, and with a capacity of 42,806 gallons.

The author is of opinion that better results would have been obtained had the contact beds been converted into percolating filters, but he was unable to recommend this to be done owing to the high cost.

In addition to the storm-water beds there is an area of about four acres of land available for storm-water treatment, which the council propose to utilise during the summer for growing tares and rye grass for the use of their horses. Some of the land previously used for treating the sewage is planted with osiers.

The final effluent shows a purification of from 87 per cent. to 91 per cent.

The whole of the refuse destructor plant, comprising furnaces, combustion chamber, boiler, fan, buildings, flues and chimney, together with approach road, tipping platform and drainage, etc., has been erected by Messrs. Heenan and Froude, Ltd., of Worcester, at a cost of about £4,000.

The plant is of the most modern and up-to-date type, and comprises a three-cell unit, back-fed with trough grates and mechanical clinkering, which the firm recommend as being far superior to the ordinary flat grate type, both in saving labour and in rapidity of destroying the refuse.

The capacity of the plant is from 18 to 20 tons of ordinary unscreened house, market and trade refuse and direct sludge, mixed in the ratio of three of refuse to one of sludge, per working day of ten hours.

A drying hearth for the reception of the sludge is formed in each cell.

Reinforced Concrete Silos at Standerton, South Africa.—General Botha himself is setting the fashion in modern silo equipment on South African farms. He has recently erected two silos on his farm Rusthof, near Standerton, made of reinforced concrete, and of a capacity of 155 tons each. They are 36 ft. in height, with an inside diameter of 16 ft. In the same district six silos, built of reinforced concrete, have been erected on the farm of Mr. Woodhouse, Platrand. This farmer is so satisfied with his investment that he proposes erecting two more. Five of these silos are 36 ft. by 14 ft., with a capacity of 118 tons each, while the sixth is 40 ft. by 14 ft., having a capacity of 138 tons.—*African World.*

Reinforced Concrete Signs in the States.—Reinforced street signs are growing in popularity in the States. They are made from white, stainless Portland cement and crushed granite, moulded by a special process which produces a hard, smooth surface, unstainable and permanently unaffected by weather conditions. The letters are moulded in a plastic state and dovetailed into the body of the concrete, making the whole work a monolithic structure. The lettering is coloured, so as to stand out against the white background. As the colours are non-fading, the signs are claimed to be indestructible and everlasting. In many cases the signs are illuminated by gas or electric light.

A House Built with Fifty-Six Varieties of Cement.—The United States Bureau of Standards is now conducting an interesting experiment in order to ascertain the wearing properties of various mixtures of cement. For this purpose there has been erected a long building the sides of which are composed of forty-eight panels, each panel about 12 ft. in height by 14 ft. in length, while the ends have each four panels; thus the entire building represents a total of fifty-six panels made of as many different varieties of cement. In each instance the composition is plastered into place in the same manner as it would be in common practice, and the object of the tests has been to determine what mixture "weathers" best; in other words, which panel will stand the sun, wind, rain, and freezing temperatures of out-of-doors and remain in good condition.

PROPOSED WORKS.

Shirehampton.—The War Office has accepted the tender of Geo. Pollard and Co., Ltd., Taunton, for the provision of concrete floors to stables at Shirehampton.

Nairn.—Tenders have been received by the County authorities at Nairn for alternative schemes in masonry and reinforced concrete for a new bridge over the Cawdor Burn, at Cawdor, and for a new bridge in reinforced concrete over the Muckle Burn, at Fornighty. Messrs. Walker and Duncan, of Aberdeen, are the engineers.

Bolton.—The Corporation have under consideration the promotion of a Bill in Parliament for the carrying out of a large water scheme, known as the Raeburn scheme, which it is estimated will cost £2,536,000.

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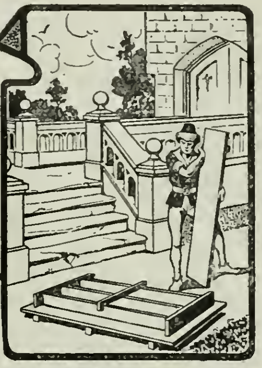


THE ADAPTABILITY OF LOCAL MATERIALS AND THEIR APPLICATION FOR GENERAL PURPOSES.

By THOMAS POTTER.

In continuation of the particulars given last month on the adaptability of materials, we now give the concluding part of Mr. Potter's article. At the end we also give a number of illustrations which have bearing on these two articles, and these illustrations show work which has been actually carried out.—ED.

GATE POSTS.

Gate posts of concrete have many advantages. When live stock pass through gates it is often an advantage for the gate to open either way. This is usually performed by hanging it in the centre of the post, but which often admits of it being

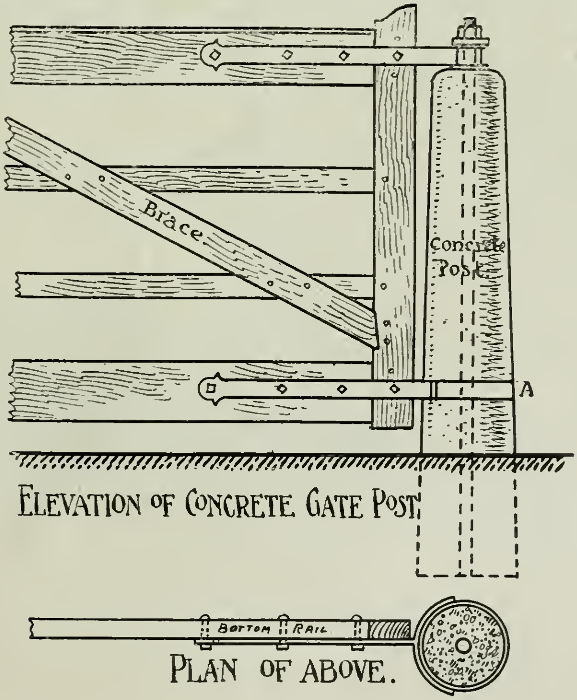


Fig. 7

opened at right angles to the post, and damage often arises through an attempt to open the gateway wider than the hangings permit. This can be remedied by casting a circular post *in situ* by means of a wood form in two parts, each part formed of solid wood and dished to a semi-circular section. A $\frac{3}{4}$-inch vertical rod, screwed and nutted on top, is embedded in the concrete. The bottom hinge revolves round a circular iron ring, 2 in. by $\frac{1}{4}$ in., built in the concrete. Gates hung in this way have a much longer life than is usually the case owing to the absence of the effects of banging from wind and rough usage. One mould is sufficient for many posts, and the cost of the latter is no more than oak. A gate and post of this description, made nearly thirty years since, are still intact.

In enclosed pastures cattle will make their way to the gate leading to the buildings—from some intuitive sagacity about the time when they are accustomed to pass through, and crowd round it. It is an advantage in that case to be able to open it from as well as towards them.

WINDOW SILLS.

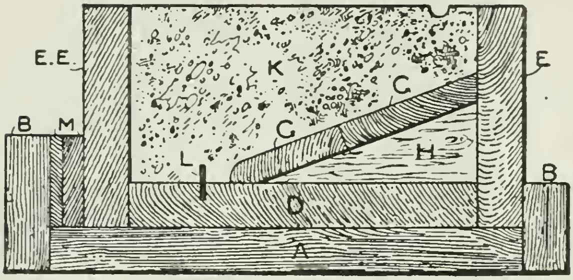


Fig. 8.

A more pretentious class of work is the casting of door and window sills. Forms for the latter are constructed as follows: Two bearers, *A*, with sides, *BB*, firmly nailed thereto are necessary; *A* may be 3 in. by $1\frac{1}{2}$ in. stuff; *BB*, 3 in. by $1\frac{1}{4}$ in.; *E* and *EE*, $1\frac{1}{2}$ in. thick, *E* being fixed and *EE* loose; *H*, blocks $1\frac{1}{2}$ in. thick and a foot or more apart, fixed to *D* and *E*, and to which *GG*, $\frac{3}{4}$ in. thick, are nailed. An iron bar, $\frac{1}{4}$ in. thick, *L*, is fixed in a groove in *D*, to form a groove in the sill for the weather bar of sill of window frame; *M*, folding wedge to tighten the side, *EE* to *D*.

CAST COPINGS.

Cast copings for thick walls where a projection on either side is necessary can be made in wood forms as shown. *A* is a bearer, 3 in. by 2 in., with side pieces, *BB*, nailed thereto; *DD*, side pieces; *EE*, ledges, 4 in. by $1\frac{1}{2}$ in., and to which the boarding, *FF*, is fixed; *GG*, blocks $1\frac{1}{2}$ in. thick and 9 in. apart, and fixed to *F*: *HH*, $\frac{3}{4}$ in. stuff in narrow widths.

Two bearers as *A* are required, and light wood or iron clamps at top to prevent the sides from spreading.

As shown, the form is in two parts, being more convenient to handle and less liable to injury by expansion.

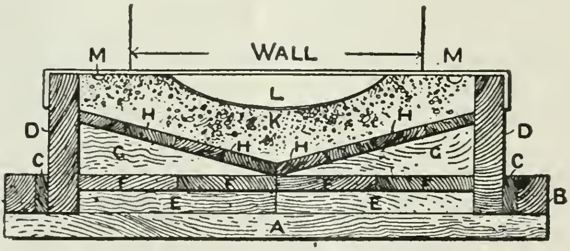
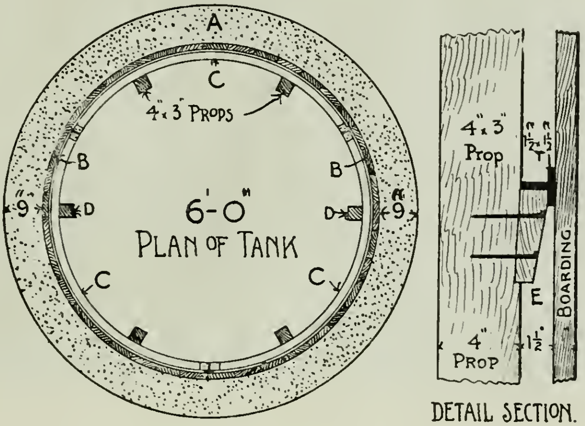


Fig. 9.

UNDERGROUND WATER TANKS.

Underground water tanks are usually executed—if circular on plan—by means of a wood drum made in sections, to admit of easy removal. This is, however, a cumbersome method, and where a number are required, as, for instance, on landed estates for cottages where the ordinary supply from wells is limited or the wells are deep, a simpler and economical method in cases of this kind is shown by *Fig.* 10, which is a plan of one 6 ft. in diameter. Rings of 1½ in. by 1½ in. by ¼ in. tee iron in three sections, bolted together by cleats at their junction, and three or four feet apart, are supported by wood uprights, and blocks fixed thereto. Inch boards are placed upright against the flanges of the tees to form a trough, into which the concrete is deposited, and necessarily the wood uprights require to be the same height as the tank is in depth.



DETAIL SECTION.

Fig. 10.

When completed, the cleat bolts being liberated, the rings and woodwork are easily removed. The top or cover can be a concrete slab 5 in. or 6 in. thick, in which a few rods may be embedded, and laid on a temporary platform. If grouted with neat cement it will be impermeable. A 3 in. cast-iron pipe should be fixed in the centre, 6 ft. in height, open at top and bottom to admit air, without which the water soon becomes foul, and have a galvanised iron wire spherical strainer fixed to the top to prevent bird droppings from passing into the tank.

LIQUID MANURE TANKS.

Liquid manure tanks can be constructed in a similar way to rain-water tanks, but without the ventilating pipe.

Where irrigation is practised adjoining rivers and their tributaries, sluices, hatches, foot and cattle bridges, and retaining walls are necessary, and in many cases these are formed of wood, and subject to rapid decay and considerable cost for upkeep. If formed of concrete the latter is almost nominal.

There are other purposes for which concrete is valuable, cow-stall and stable divisions, channel gutters, fence posts, and lintels, for instance, but for which primary instructions and advice as to suitable local materials and their application are necessary, and the absence of which causes the use of concrete in many agricultural districts to be as little known and appreciated as was the case fifty years since.

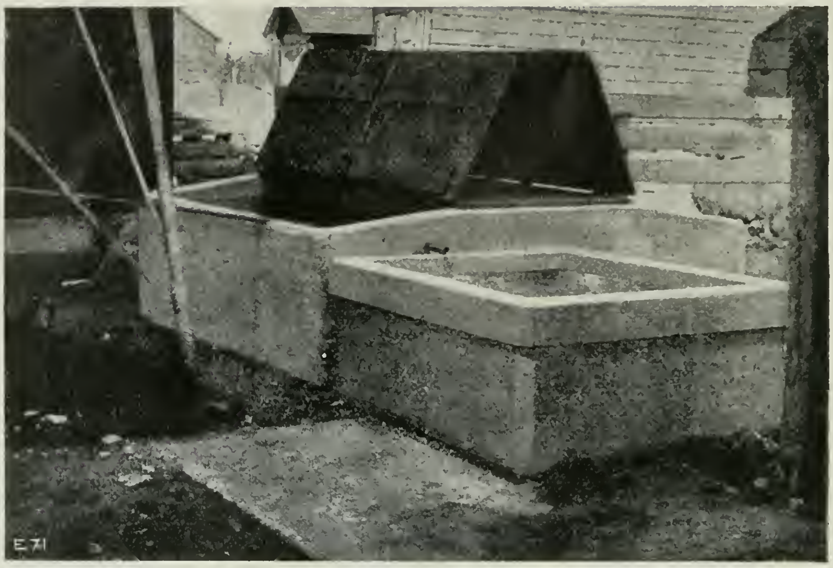


Fig. 11 Showing Covers for Concrete Troughs.

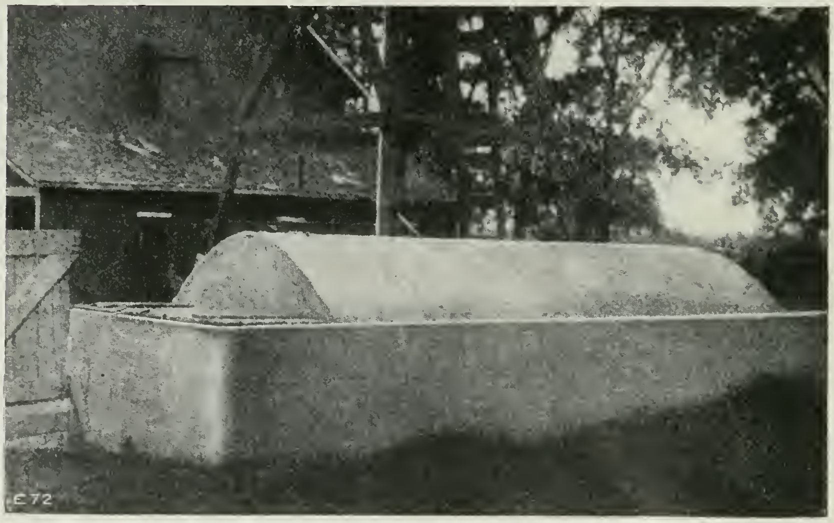


Fig. 12. Covered Concrete Water Supply Tank and Troughs.

These illustrations show tanks and troughs which have been built by farm labour in U.S.A. The tank shown in Fig. 12 is 10 ft. by 30 ft. by 6 ft. deep. An arched concrete cover keeps out dirt and cold, and two wooden covers at the end protect the openings where stock is watered.

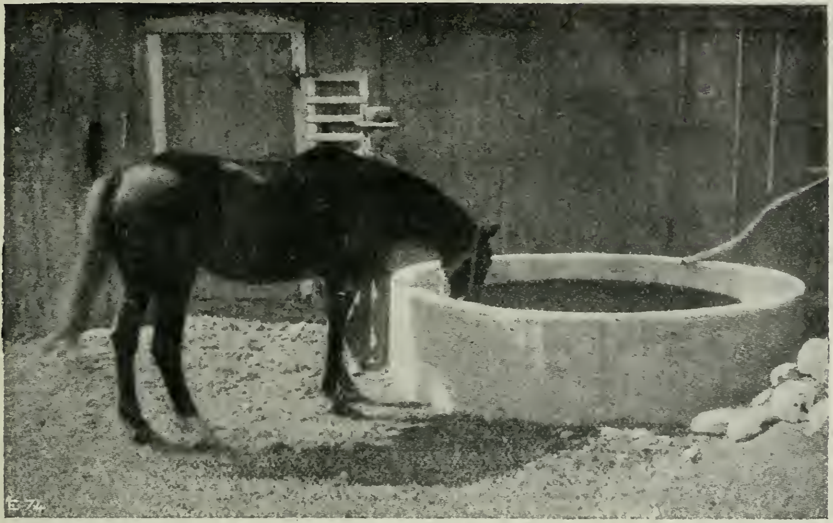


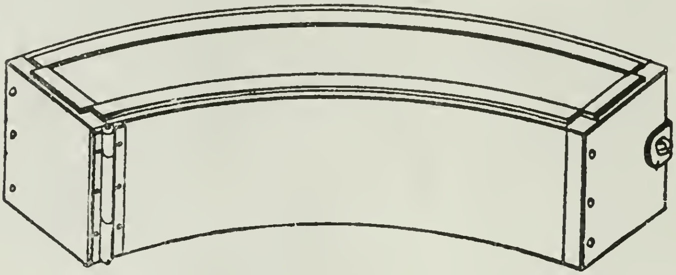
Fig. 13. A Circular Trough

Fig. 14. Cow Stalls, Mangers and Floor of Reinforced Concrete.

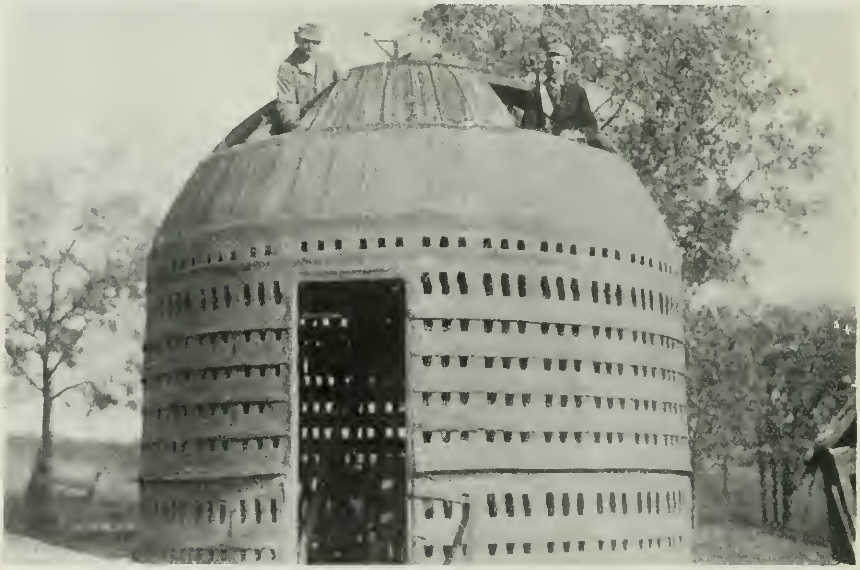
A CONCRETE CORN CRIB.

One of our illustrations on this page shows a corn crib made of concrete blocks. The advantages of such a structure as compared with one of wood are its very low cost and its fire-resisting qualities; also, it is rat-proof.

This crib is built of blocks, and allows of easy placing of reinforcing wires. The flange on block carries the reinforcing wire, and projects from the wall to form water table over ventilated openings.



Form of Mould used for Concrete Corn Crib.



A Reinforced Concrete Corn Crib Erected on a Farm at Grand Rapids, Iowa, U.S.A.

The structure has a reinforced circle taper block self-supporting roof, with a ventilated cement block flue in the centre of the crib.

The roof and walls are watertight. Fourteen feet silo moulds were used to make the blocks for this corn crib. The walls are 2½ in. thick, and the roof is 2 in. thick.

The structure has a foundation 8 in. wide by 7 in. deep, and is well reinforced. The floor is 2½ in. thick. The shallow foundation allows the structure and contents to come and go with the frost without damage.

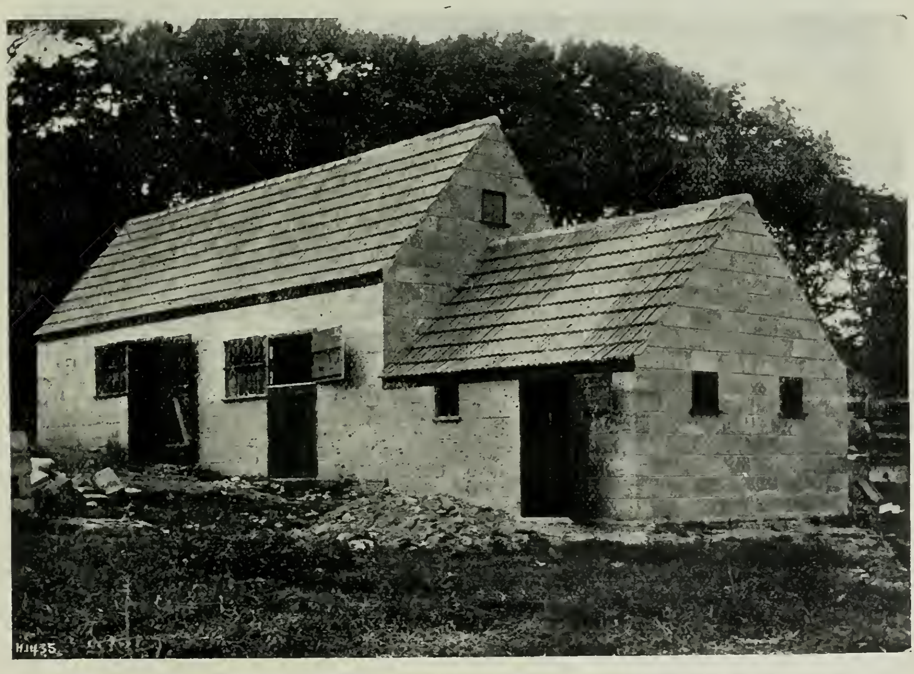
The front row of blocks are settled in the green concrete of floors. On the top of the third row of blocks a rat-proof extension projects from the wall 3½ in., and small wire mesh is placed on the inside of wall over openings below extension to exclude vermin. A galvanised iron door is hung on the gas pipe door frame which excludes the rats at this point, leaving no opening at which they can enter the crib.

The roof is made of circle blocks 2 in. thick and tapered to suit the circle in which they are placed, and reinforced at the top to withstand the thrust from above. The cost of erecting this corn crib in America worked out at a total of $48.50; of this the roof is approximately one-third of the total cost. The weight of the roof is 4,100 lb.

SOME FARM BUILDINGS.

The illustrations below show some farm buildings erected on an estate in Norfolk.

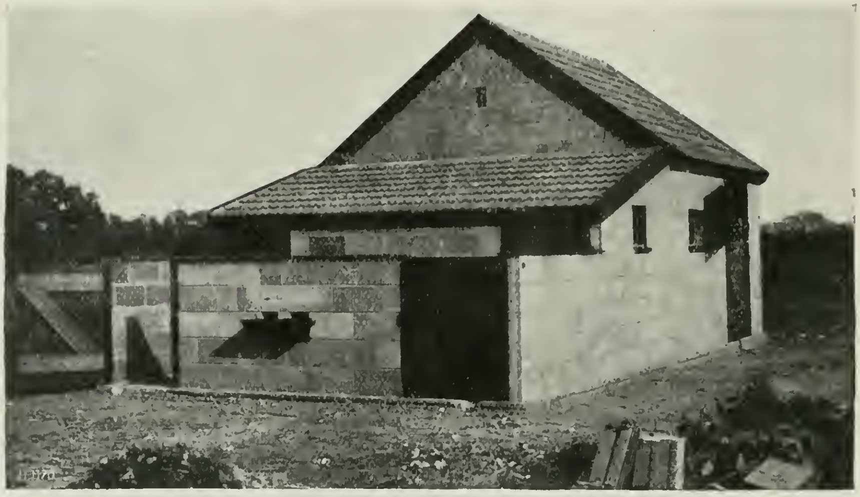
These buildings comprise a harness room, stable for two horses, a cow byre for four cows, and four pigsties. These buildings have been erected in concrete blocks. The walls are 4½ in. thick. The roofs are of concrete tiles.



Some Farm Buildings, Wayford Wood, Norfolk.

A similar type of farm building erected on the same estate shows two cow-stalls, a fodder-room, and two pigsties. In the courtyard there is a trough made entirely of concrete, with a shoot from the outside wall to the trough.

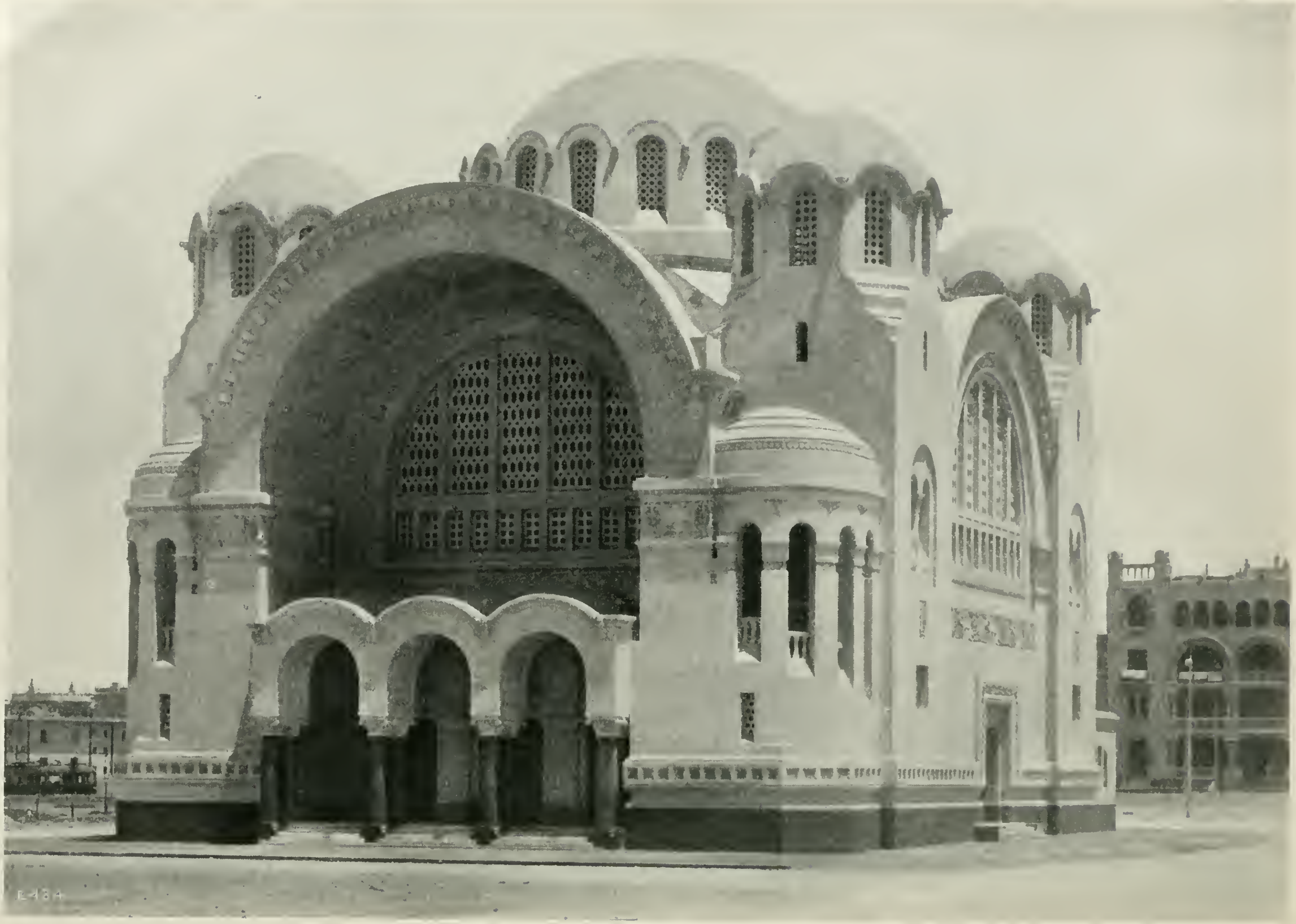
From the fodder-room there is a feeding passage at the head of the cow-stalls. The manger is of reinforced concrete, and the Danish principle of having it low has been adopted. The walls are all built of concrete $4\frac{1}{2}$ in. thick, the size of each block being 18 in. by 9 in. by $4\frac{1}{2}$ in. The roof is of concrete tiles (glazed red). The building is fitted with a concrete tank sunk in the ground, to which all the liquid manure is drained.



Cowshed, Fodder-room and Double Pigsty.

In our next issue we propose dealing with ornamental concrete in the garden and on the estate.

Our readers are invited to send in suggestions as to subjects they would like to have dealt with in these "supplement" pages.



Principal Entrance.
The Basilica, Heliopolis Cairo
(*See p.* 424.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XI., No. 8. LONDON, AUGUST, 1916.

EDITORIAL NOTES.

REINFORCED CONCRETE IN THE FIRE AT THE EDISON PHONOGRAPH WORKS, WEST ORANGE, N.J.

THE various reports received in connection with the fire at the Edison Phonograph Works at West Orange, N.J., on December 9th, 1914, are very interesting and instructive, and may be divided under three heads—viz.: An account of the actual fire itself, the construction of the buildings affected, and their re-instatement after the fire. With regard to the actual fire, apart from the defective fire appliances and the deficiency of water, it would never have attained to the dimensions it did had the buildings been properly divided into fire-tight compartments by division walls and had the exposure risk been properly provided against by iron window sashes and wired glass.

In looking at the plan of the various buildings one is not so much surprised at the destruction wrought as that it was not a great deal more. When will proprietors of such establishments as these realise that they are giving the fire department, however well organised, an impossible task when once a fire has fairly started among inflammable contents?

With regard to the construction of the buildings, they were of various types, such as wood frame, wood frame covered with iron, brick buildings of ordinary construction and reinforced concrete structures. The latter class predominated. Of the first three types little need be said, as they were soon heaps of ruins; but the latter type, the reinforced concrete buildings, justified their existence and for the most part required reinstatement only to make them again available for use. The results of this fire have shown that of all fire-resisting constructions, reinforced concrete comes out of the ordeal highly satisfactorily, especially when one considers that some of the buildings were erected so far back as 1905, when the work executed was not up to modern standards. The whole of the reinforced concrete buildings survived the fire with the exception of a part of building No. 11, amounting to a very small percentage of the whole. When it is taken into consideration that in some instances the limit of all fire-resisting materials was reached—*i.e.*, the fusing point, and that temperatures exceeding, perhaps, 2,500 deg. F. were reached, it demonstrates that this form of construction is the best fire-resister.

The American Concrete Institute have issued a special report on the fire, and among other conclusions as to construction have arrived at the following:

(*a*) That the best type of construction is one which eliminates corners and presents flat or rounded surfaces to the action of the fire. That interior columns of circular or octagonal section offer greater resistance to fire and are less liable to damage than columns of square section, and that the elimination of sharp corners in the floor construction is desirable.

(*b*) That good construction requires a sufficient number of lateral ties or hooping in the columns, and that such construction would offer greater resistance to fire.

(*c*) That in the beam and girder type of construction, in order to fully develop T-action, the slab should be cast at the same time that the beams and girders are poured, and there should be adequate ties between the reinforcement of the beams and girders and that of the slab.

These conclusions conform generally to modern practice, which, apart from the lessons of this fire, are mostly inculcated in the London reinforced concrete regulations.

Observing these conclusions and the general regulations as to division walls, iron frames and wired glass, as also the enclosure of all staircases, lifts, etc., with sufficiently stout fire-resisting material, and an efficient sprinkler installation, a fire, however fierce locally, should be confined to the compartment in which it originated.

With regard to the reinstatement of the reinforced concrete buildings, it was always a matter for controversy whether such buildings, being more or less monolithic, could be reinstated if damaged by fire. The very interesting address given by Mr. T. L. Condron, the engineer consulted by Mr. Edison after the fire on the work of reinstatement and the methods employed by him, is excellent reading. He states that the columns suffered the most damage, but it was mostly on the surface; that, due to longitudinal expansion, the exterior columns suffered the most. He states also that: "It is worth while to note the ease with which reinforced concrete columns were repaired or replaced. It was a simple matter to remove the damaged concrete, surround the sound concrete core with spiral hooping, and pour new concrete or cement mortar into enclosing sheet metal forms." Other interesting details as to the condition of the beams, and the method of repair, are described, and the conclusion at which he arrives is that the building is now sounder and stronger than it was even before the fire.

THE NATIONAL PHYSICAL LABORATORY.

IN a previous issue we dealt with the great need for research work of all kinds, and deplored the lack of support given to the National Physical Laboratory by the Government, as the work of the Laboratory was being seriously hampered by financial difficulties, which justified a grant from public funds. We have before us now the report of the Laboratory for the year 1915-16, and are happy to note that the Government are making full use of the various departments for testing purposes, and apparently giving practical support, which we hope will be continued after the war is over. Unlike the previous report, no mention is made of financial difficulty, and we, therefore, assume that the appeal which was made to the Prime Minister some time ago for a grant has met with success, and proper research work is being encouraged in this country as it is in others.

The work of the Laboratory has naturally been greatly affected by the war, but this is only to be expected, both as regards the depletion of the staff and the nature of the work undertaken. A great deal of the ordinary research work has been suspended and special investigations have been undertaken for Government departments. The work has increased to such an extent that a considerable number of men, disqualified for military service, and women have been engaged, and it is interesting to note that the committee specially commend the latter for the efficient manner in which their work has been done. A number of voluntary assistants have also given their services to the laboratory, and in this way the work has been well carried on. It is to be hoped that the foundation is thus being laid for a properly organised and extensive system of scientific research work in this country, which will apply to every industry, and assist us in our endeavours to secure a foremost place in the trade of the world.

In the engineering department the comparative tests for the years 1915 and 1916 show a slight increase, the total number for 1916 being 640, as compared with 617 for the previous year, and of these 332 dealt with the strength of materials. In these tests various subjects were dealt with, such as the fatigue resistance of materials under combined stresses, the hardness and wearing properties of metals, the resistance of wood to reversals of stress, and the resistance of the tension members of a structure to lateral vibrations. There are several interesting points in connection with these and the other tests conducted by the department which cannot be dealt with here, but which should be taken up and considered by all members of the engineering profession.

The National Physical Laboratory is to be congratulated on the amount of work done and the valuable services rendered to the country by the investigations for war purposes, and firm support should be given to what constitutes an important factor in the progress of the trade and industry of the whole country during the next few years.

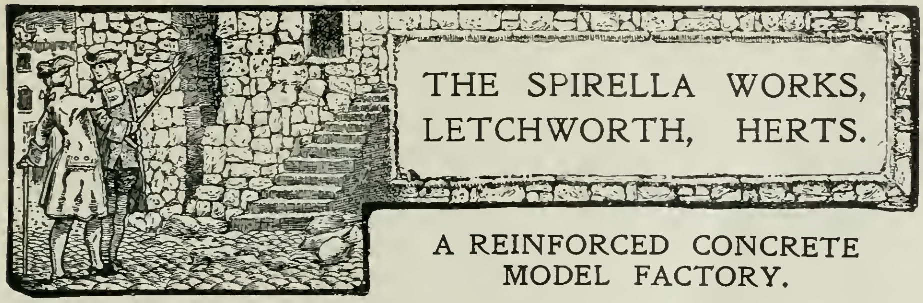
THE FUTURE OF CONCRETE BLOCK CONSTRUCTION.

THERE is a great tendency amongst architects and engineers to under-estimate the value of concrete blocks and slabs in building work of all kinds, and the matter is such an important one to those connected with the industry that we feel called upon to make a few remarks on the subject.

We could quote numerous instances of dissatisfaction occurring through the use of concrete in this form, and generally there is some ground for the complaints made, despite the fact that excellent work can be executed with the material. The trouble arises through cracks occurring after the work has been executed some time, probably when the contractor has completed his contract, and the cause of these cracks can only be traced to one source, that is, the insufficiency of the seasoning of the concrete.

Manufacturers of concrete slabs and blocks should realise that by supplying material which is not properly seasoned they are doing damage to their own business, and quite unnecessarily so. If the concrete is not *thoroughly* seasoned when placed in the work it will become so afterwards, and this means contraction, with the consequent cracks. Many architects now prefer to use fireclay or terra-cotta blocks, as they have had trouble with concrete, and in a baked substance there is no fear of movement. We know of one large building in London where nearly all the partition blocks are of concrete, with the exception of one set of rooms which were executed in terra cotta, and when the maintenance period expired it was found that in every instance the concrete partitions were cracked, whereas not a single crack occurred in the terra cotta. This is a serious consideration to the client and architect, and it gives concrete slabs a bad reputation, whereas they are quite capable of giving a first-class form of construction.

The trouble lies in the fact that those supplying the concrete sacrifice efficiency in order to obtain a quick return for the outlay entailed in the manufacture, and they will not keep a sufficient stock of slabs and blocks in hand to execute large orders. We know that it is not good business to keep a large amount of capital locked up for weeks in material which is not saleable, but at the same time it should be considered as an *essential* part of the process of manufacture that a sufficient period be allowed for seasoning, and by this we do not mean the minimum period generally allowed, but the maximum required to give really sound blocks which will stand well in the work and give entire satisfaction to the purchaser. It is only by a proper appreciation of this fact that the industry can ever be raised to the high standard to which it is entitled, and enable concrete products to take the lead on the market.



THE SPIRELLA WORKS, LETCHWORTH, HERTS.

A REINFORCED CONCRETE MODEL FACTORY.

By ERNEST G. W. SOUSTER.

An interesting example of factory construction is given in the following pages.—ED.

The Garden City of Letchworth is now famous all over the world as an example of what the future manufacturing town may be, and it is, therefore, interesting to state that the finest factory building in it has been erected in great part of reinforced concrete.

The building not only provides for the workrooms and offices of the company, but recreation rooms, rest rooms, gymnasium, roof garden, class room, bath rooms, and a large concert hall with seating accommodation for 1,000 persons, are provided for the employees.

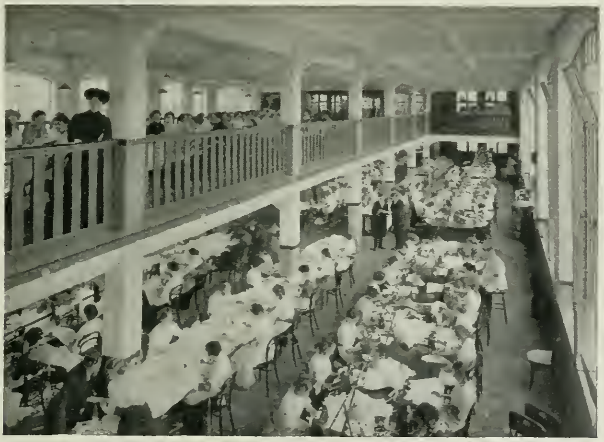
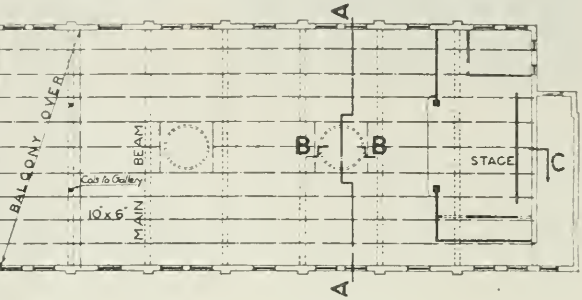


Fig. 1. Workroom showing Central Gallery.
A Reinforced Concrete Model Factory, Letchworth, Herts.

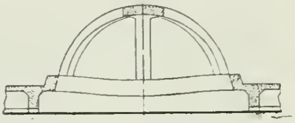
The management believe that they have duties beyond the earning of dividends, and apart from that they hold that the provision of healthy and happy surroundings for their workpeople is, in the end, a paying proposition.

From the plan it will be seen that the structure at present consists of two blocks, and as the business increases it is proposed to add two further blocks to complete the hollow square. This first is 172 ft. long by 55 ft. wide, and is almost entirely devoted to the business of the company. The basement is used for stores, the ground floor as offices, and the first floor and gallery as workrooms, whilst the top floor, adjoining the roof garden, is used as rest and recreation rooms.

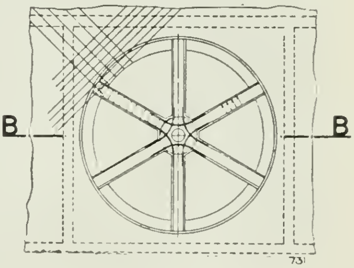
The second block, part of which is now being used for the manufacture of munitions, is 115 ft. by 55 ft., and the concert hall, already mentioned, occupies its top floor. This concert hall is equipped with stage, dressing rooms, and everything necessary for theatrical displays, and has a balcony at end opposite stage.



Plan.



Section BB.



Plan of Light.

Fig. 3. Detail of Domes to Concert Hall.

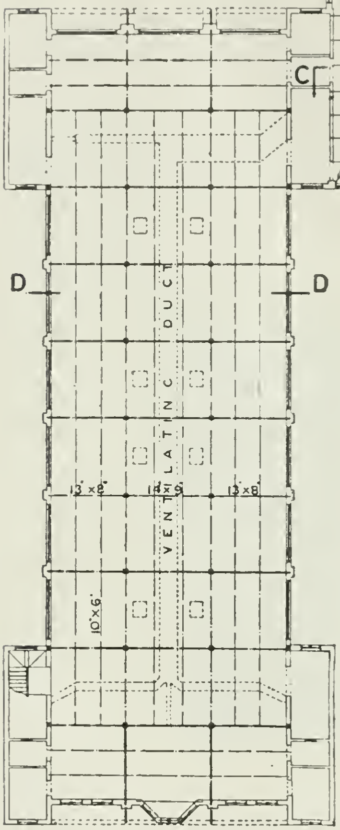


Fig. 2. First Floor Plan.

A Reinforced Concrete Model Factory, Letchworth, Herts.

Fig. 4 shows the exterior of the building, by which it will be seen that it is faced with brickwork with concrete window cills and heads showing on surface.

A unique feature of the elevation is the top floor of the end pavilions, which extends out to the face of the projecting bays below. This floor and the

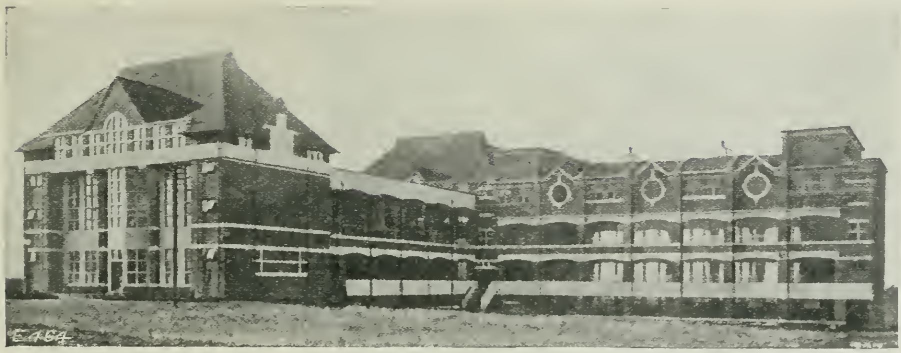
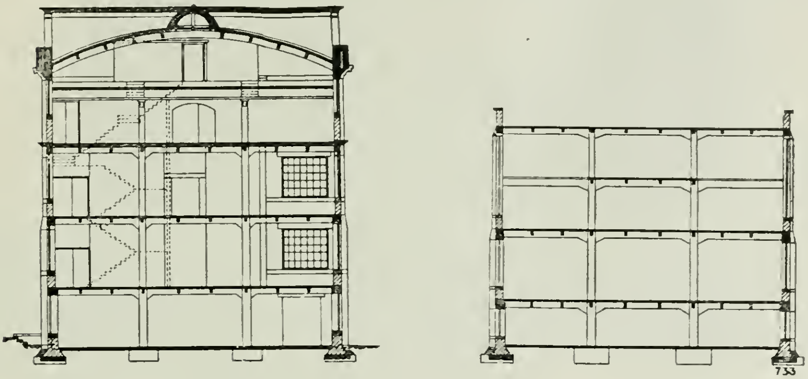
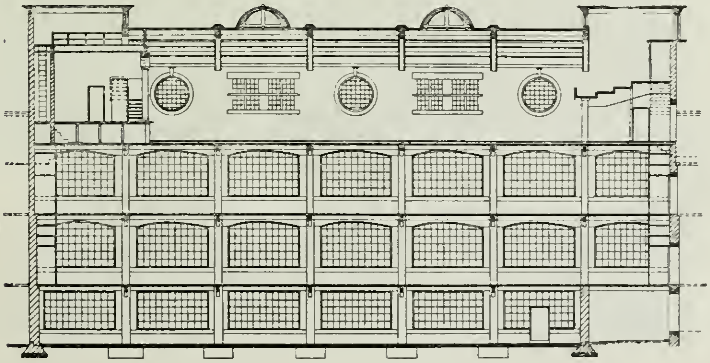


Fig. 4. Exterior View of Building.



Cross Section AA.

Cross Section DD.



Longitudinal Section CC.

Fig. 5. Sections.

A Reinforced Concrete Model Factory, Letchworth, Herts.

enclosing wall are carried on a deep beam, supported by reinforced cantilevers projecting from the wall surface below.

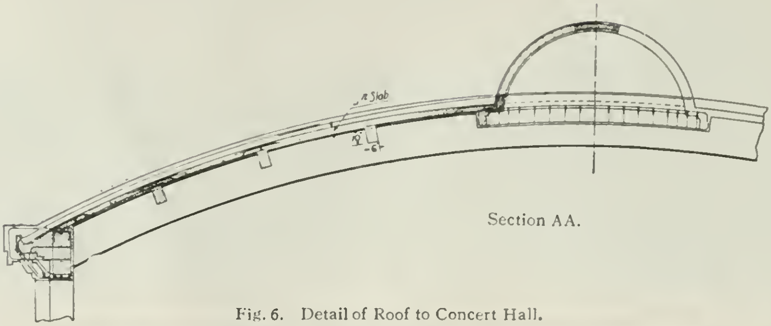


Fig. 6. Detail of Roof to Concert Hall.

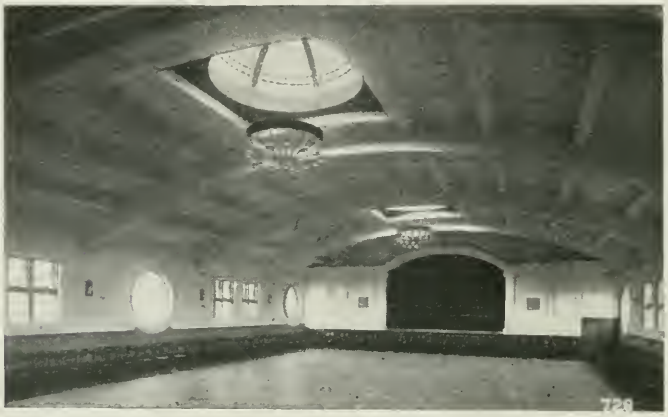


Fig. 7. Interior of Concert Hall.

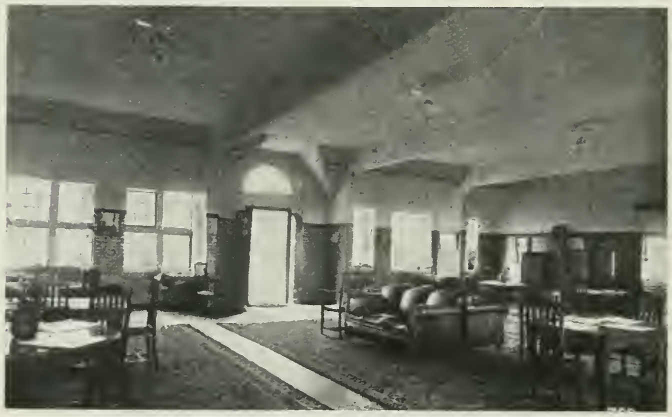


Fig. 8. Rest Room, showing Beams Left Exposed.
A Reinforced Concrete Model Factory, Letchworth, Herts.

With the exception of the enclosing brick walls the whole of the structure is of reinforced concrete, of which the most interesting feature is the roof of

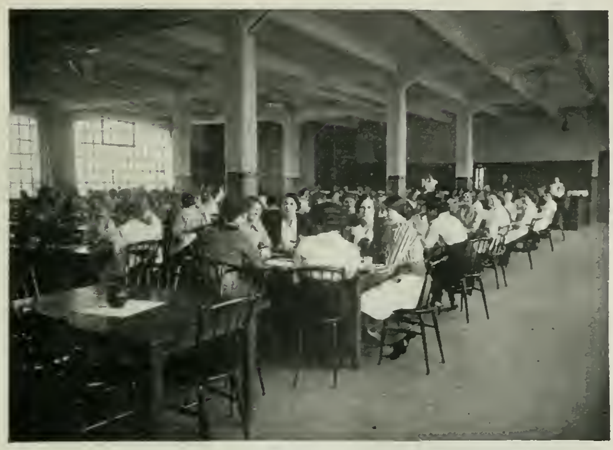


Fig. 9. Interior of Dining-room, showing Construction.
A Reinforced Concrete Model Factory, Letchworth, Herts.

the concert hall. This, as will be seen from the cross section AA of building, *Fig.* 5, is roofed by a concrete slab, resting on arched beams springing from wall to wall, and these have eight longitudinal stiffening beams, 10 in. by 6 in., between them. Owing to the large span a depth of 36 in. was necessary for these arched beams, and to obviate an excessive depth showing in the hall they project above the general roof surface (see elevation).

The roof itself consists of a $3\frac{1}{2}$-in. slab, and the whole surface, including the projecting beams, is finished with asphalte. *Fig.* 6 shows a section through this roof and the construction of the glazed reinforced concrete domes which break the monotony of the ceiling is shown in *Fig.* 3. The gallery to this hall is also of reinforced concrete and is carried by two main beams running from back wall to two columns in the auditorium.

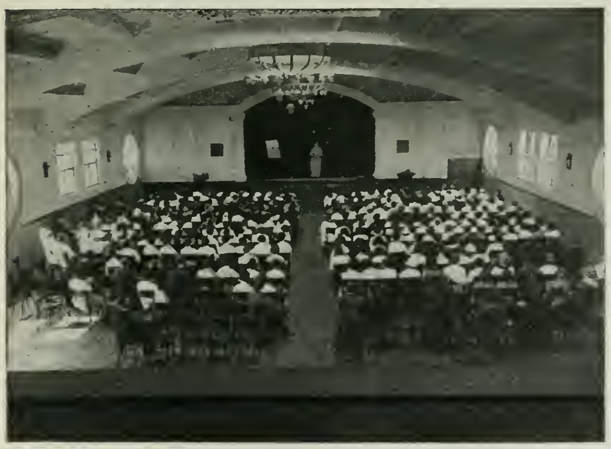


Fig. 10. Concert Hall.
A Reinforced Concrete Model Factory, Letchworth, Herts.

Another feature worthy of notice is the gallery on the first floor of Block 1, which runs down the middle of room instead of being attached to the outer wall.

The use of a central gallery is common in America, and the lighting results gained by it, as compared with the central well not top-lighted, justify its extended use in future buildings in this country.

As regards the ventilation, warmed air in winter, and cold air in summer, is pumped into the building by means of a trunk running down the centre of rooms between the longitudinal beams. Where this trunk meets the main beams cast-iron tubes are introduced and the design of members varied accordingly.

The architect for the work was Mr. C. H. Hignett, Licentiate R.I.B.A., of Letchworth, at present serving with H.M. Forces somewhere in France. The whole of the reinforced concrete work was designed in conjunction with him by the Indented Bar and Concrete Engineering Co., Ltd., of Queen Anne's Chambers, Westminster, and the general contractor was Mr. H. Hurst, of Letchworth.

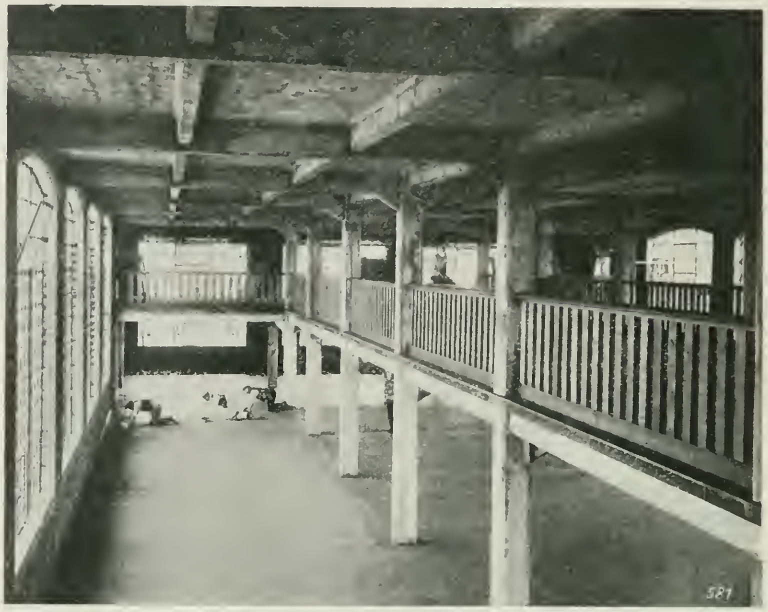


Fig. 11. A Workroom, showing Central Gallery.

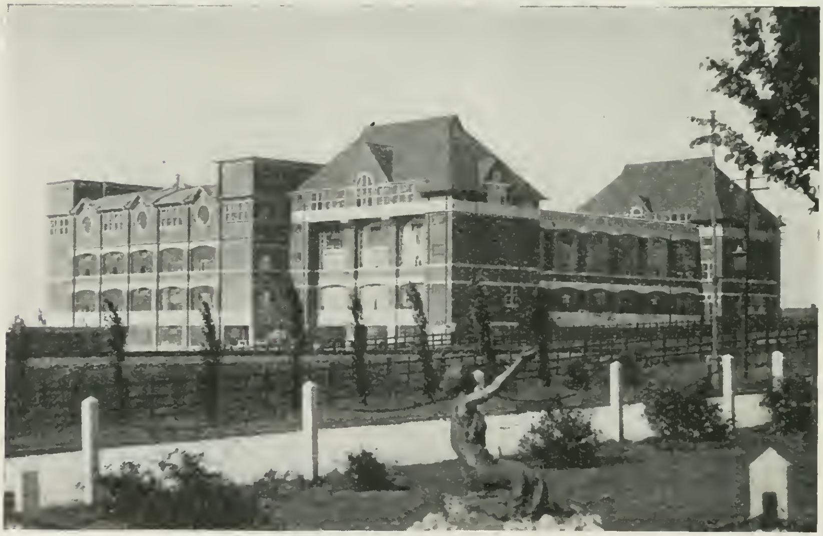


Fig. 12. Rear Elevation.
A Reinforced Concrete Model Factory, Letchworth, Herts.

RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

Continued from July issue, p. 369.—ED.

PART III (*continued*).

(*b*). *STATEMENT OF THE WRITER'S THEORY* (*continued*).

The following analyses show the procedure when the safe shear is limited by the concrete stress in the web (the second condition).

7. *Direct inclined compressions in rectangular beams.*

It will be seen by reference to *Fig.* 26 that the maximum stress in the inclined compression will occur at the centre and at the end.

The stress at the centre will be safe if the beam has been designed for resistance moment in the usual way, the stress in that case varying from a maximum of C (not more than 600) at the upper face to zero at a depth of n.

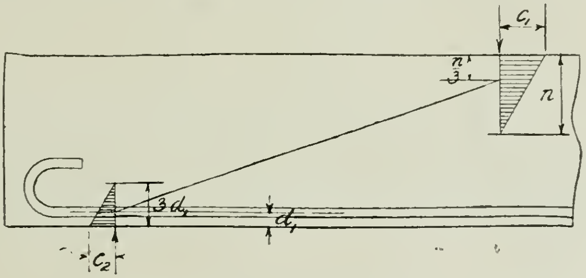


Fig. 26. To show Stresses in a simple Beam resisting the whole Shear by Inclined Compression.

If we consider the conditions of equilibrium of a vertical section just outside the support, and neglect the resistance to tension of the concrete at the top of the beam, it will be seen that the only forces acting are the horizontal compression from the hook, and the tension in the bar. To maintain equilibrium, the resultant of the first must be on the centre of the bar (assuming the bars incapable of resisting appreciable bending stresses).

It follows that if d_1 is the distance of the bar from the lower surface, the stress at the end will vary from c_2 at the lower surface to zero at a distance of 3 d_1 up.

It follows, as the total compression is assumed constant from support to load, that if d_1 is at least equal o $\frac{n}{3}$, c_2 will not be greater than c_1, and will therefore be safe.

It will be found that when the horizontal component of the inclined compression can be equal to the flange forces of the resisting couple at the centre, the vertical component will necessarily be equal to the vertical shear.

In other words, for a simple beam with a sufficient hook, with reinforce-

ment running the whole length at a distance from the bottom of d_1 *not less than* $\frac{n}{3}$ *failure will not occur until the full moment of resistance has been reached.*

This is a most important result, and shows that no shear reinforcement is ever necessary in such a beam, since, if the safe stresses are not exceeded by the bending moment at the centre, they will not be exceeded elsewhere.

It proves, also, what the writer has long maintained, that it is useless to attempt to test the safe resistance to shear of concrete beams unless the test beams are constructed as **T** beams, or heavily reinforced in compression.

It will be shown in the following pages that even if the bars are not quite $d_1 = \frac{n}{3}$ from the bottom, the safe stress will not necessarily be exceeded at the ends, and the above conclusions may still hold.

8. *Approximate limit of shear resisted by direct inclined compression in non-continuous* **T** *beams, or rectangular beams with compression reinforcement.*

In such beams the resistance to compression at the centre has been increased by the addition of the flange of the **T** or the compression bars, and as this increase of resistance does not help the web, the limit to the inclined compression will often be found in the latter near the support.

To obtain an approximate idea of what the inclined compression is worth let us take

$$n = 0{\cdot}36\ d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

whence—

$$\frac{n}{3} = 0{\cdot}12\ d$$

$$d_1 = 0{\cdot}12\ d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

whence— $h = d + d_1 = 1{\cdot}12\ d$

and— $a = 0{\cdot}88\ d$

and— $d_1 = 0{\cdot}136\ a$ (see *Fig.* 27)

These two assumptions (1) and (2) are generally near the truth in practical cases.

In this approximate analysis we will neglect the possible assistance of concrete or top steel at the end. (Considered later.)

Then the maximum horizontal compression of inclined compression that can be resisted—

$$H = 3\ d_1 \times d \times \frac{c}{2}$$

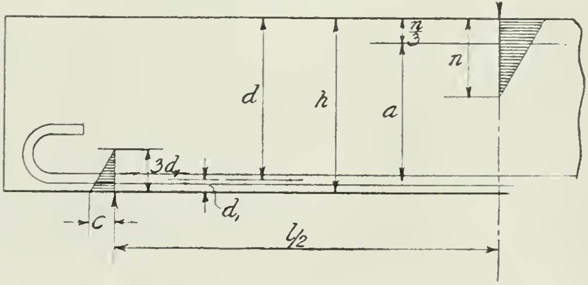


FIG. 27. To show Approximate Limit of Shear resisted by Inclined Compression.

As the shear resistances are generally put in terms of *b*, *a*, it will be convenient to do the same and rewrite the above—

$$H = 0{\cdot}204\ a\ b\ c \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The rise of inclined compression is *a*.

For single concentrated loads the rise is uniform in a distance $\frac{l}{2}$ (where l is the span).

Hence—

$$\text{Shear} = 0{\cdot}204\ a\ b\ c \times \frac{a}{\frac{l}{2}}$$

$$= 0{\cdot}408\ a\ b\ c \times \frac{a}{l}$$

Putting $c = 600$, this gives the following values for difference ratios of $\frac{l}{a}$:—

$$S = \frac{244\ b\ a^2}{l}$$

Span divided by Radius Arm.	Resistance to Shear.
$\frac{l}{a} = 2$	$122\ b\ a$
4	61
5	49
10	24·5
15	16·2
20	12·2

It will be noticed that up to $\frac{l}{a} = 4$ the resistance to shear exceeds the safe shear by diagonal tension if taken at $60\ b\ a$ as in L.C.C. Regulations.

For uniform loads.—Remembering that the slope of the parabolic stress curve will be a in a length $\frac{l}{4}$, we have as before—

$$\text{Shear} = 0{\cdot}204\ a\ b\ c \times \frac{a}{\frac{l}{4}}$$

$$= 0{\cdot}816\ a\ b\ c \times \frac{a}{l}$$

Span divided by Radius Arm.	Resistance to Shear.
$\frac{l}{a} = 2$	$244\ b\ a$
4	122
5	98
10	49
15	32·4
20	24·4

It will be noticed that for $\frac{l}{a}$ up to 8 the safe shear exceeds that allowed by the L.C.C. under the formula $60\ b\ a$.

To make the formula applicable to all cases, let—

l_1 = the "point load span"—that is, the span on which the load on the beam would produce the actual maximum bending moment if concentrated at the centre.

In any case l_1 may be calculated from the above, or graphically as in *Fig.* 37*a*.

It will be obvious that for—

Single concentrated loads ... $l_1 = l$
Uniform loads ... ... $l_1 = \frac{l}{2}$
Two point loads at third points $l_1 = \frac{2}{3}l$

Then the formula may be written—

$$S \doteq 244 \frac{b\,a^2}{l_1}$$

or—

$$S = 150 \frac{b\,h^2}{l_1}$$

It should be noted that not only are the results often greater than the shear obtained from diagonal tensions, but they may be used in combination with other systems for resisting shear, whereas diagonal tensions, for reasons given in (4), may not.

For rolling loads.—In the case of rolling loads the resistance to shear depends not only on the rates of span to depth, but also on the position of the load, and it so happens that the resistance is greatest where the shear is greatest—*i.e.*, when the load is nearest the support—which makes this type of shear resistance specially valuable for such loads.

If the load W is at a distance of $x\,l$ from the left-hand support, the shear resistance by inclined compression is given by

$$S = 0{\cdot}204\, a\, b\, c \frac{a}{x}\, l$$

and the shear across the section by—

$$S = \frac{W \times l\,(l-x)}{l} = W\,(1-x)$$

It will be seen that the first varies from infinity for $x\,l = 0$, to something small when $x\,l = l$, whereas the second varies from $S = W$ when $x\,l = 0$, and $S = 0$ when $x\,l = l$ or $(x = 1)$.

Although, therefore, the resistance is always adequate with the load in either extreme position, there may be conditions with the load near mid-span when the resistance by inclined compression is not sufficient acting alone.

9. *Calculation of inclined compression taking tension of concrete into account in simple beams.*

It will be shown in the following analysis that by taking the tensile resistance of the concrete into account, the value of the inclined compression may be increased.

In the previous analysis of the conditions at the support we found that the compressed area at the end had to be limited to a height of $3\,d_1$ from the lower surface so as to equilibrate the tension in the bars T_1.

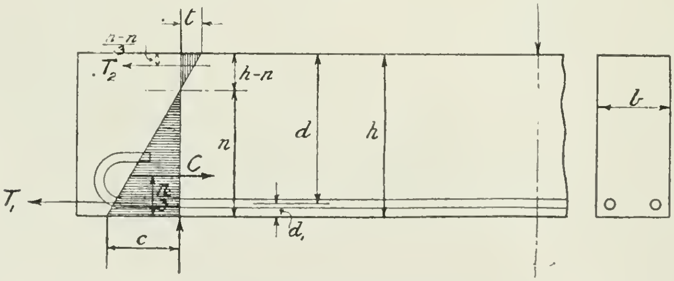


FIG. 23. TO SHOW INCREASE OF INCLINED COMPRESSION IN A SIMPLE BEAM WHEN TENSION IN CONCRETE IS CONSIDERED.

It will be seen if a tensile force T_2 exists near the top surface, the point of action of C (see *Fig.* 28) need not coincide with T_1, but may be above it, and in that case C may have a considerably greater value.

It is thought that the conditions assumed in *Fig.* 28 are self-explanatory, with the remark that the bars T_1 are supposed slipped, and hence free to have any stress apart from their position and distance from the neutral axis.

The section is assumed plane after bending.

We may at once write down the following equations—

$$\frac{t}{c} = \frac{h-n}{n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

because stress diagram is linear.

Equating the total forces—

$$T_2 + T_1 = C$$

$$b\,(h-n)\frac{t}{2} + T_1 = b\,n\,\frac{c}{2} \quad . \quad . \quad . \quad . \quad (2)$$

Equating moments about the bottom face—

$$T_2\left(h - \frac{h-n}{3}\right) + T_1\,d_1 = C\frac{n}{3}$$

$$b\,(h-n)\frac{t}{2}\left(n - \frac{h-n}{3}\right) + T_1 d_1 = b\,n\frac{c}{2}\,\frac{n}{3} \quad . \quad . \quad (3)$$

Multiply (2) by d_1 and subtract from (3)—

$$b\,(h-n)\frac{t}{2}\left(h - \frac{h-3}{3} - d_1\right) = \frac{b\,n\,c}{2}\left(\frac{n}{3} - d_1\right)$$

Substitute $t = c\dfrac{h-n}{n}$ from (1)—

$$b\,(h-n)\frac{c}{2}\left(\frac{h-n}{n}\right)\left(h - \frac{h-n}{3} - d_1\right) = \frac{b\,n^2\,c}{2}\left(\frac{n}{3} - d_1\right)$$

Multiplying out and cancelling

$$n\,(-3\,h^2 + 6\,h\,d_1) + (2\,h^3 - 3\,h^2\,d) = 0$$

$$n = \frac{h\,(3\,h - 3\,d_1)}{3\,(h - 2\,d_1)} \quad . \quad . \quad . \quad . \quad (4)$$

It is curious in cancelling out that the equation just misses being a cubic, the third and second powers all cancelling. This is due to the fact that the distance between T_1 and T_2 is a constant, and not a function of n as in other problems to follow.

It will be interesting to consider the special case when—

$$\begin{aligned} d_1 &= 0{\cdot}12\,d \text{ (as before)} \\ &= 0{\cdot}107\,h \\ n &= \frac{(1 - 0{\cdot}321)\,h}{3\,(1 - 0{\cdot}214)} = 0{\cdot}712\,h \\ &= 0{\cdot}91\,a \end{aligned}$$

Note in passing how little n varies with d_1, being 0·712 h with $d_1 = 0{\cdot}12\,d$ and 0·66 h with $d_1 = 0$.

Having determined n, we can find what value of t corresponds to $c = 600$—

$t = 600 \times 0{\cdot}282 = 235$ lb./in.^{2} 0·718, see formula (1)

This is just about the ultimate value, and it would, therefore, be unsafe to make any use of the increase in the inclined compression due to it.

Note, however, that in **T** beams this stress would be much reduced, and in that case might be safe to use.

The above calculations would in any case not be often used as they give an inclined compression greater than the centre section is as a rule designed to resist, except in the case of beams with compression reinforcement near the centre, or beams deeper in the centre than at the end.

10. Calculation of inclined compression taking tension of concrete into account in **T** *beams.*

In this case conditions are as before, except that at the top our tension flange has a width $B = M\,b$ (see *Fig.* 29) where M is a constant.

Our equations then become—

$$\frac{t}{c} = \frac{h-n}{n} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

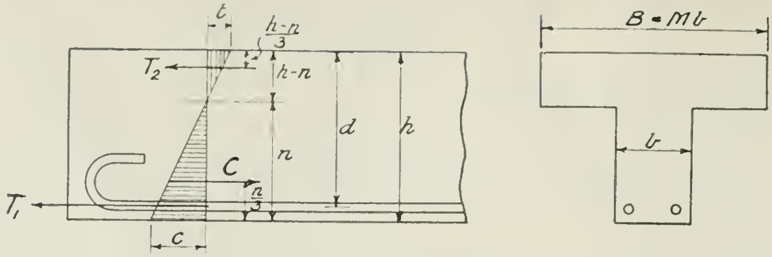


FIG. 29. TO SHOW INCREASE OF INCLINED COMPRESSION IN **T** BEAMS WHEN TENSION IN TOP FLANGE IS CONSIDERED.

$$M\, b\, (h-n)\frac{t}{2} + T_1 = b\, n\, \frac{c}{2} \quad . \quad . \quad . \quad . \qquad (2)$$

$$M\, b\, (h-n)\, \frac{t}{2}\left(h - \frac{h-3}{3}\right) + T_1\, d_1 = b\, n\, \frac{c}{2}\frac{n}{3} \quad . \quad . \qquad (3)$$

Multiplying (2) by d_1 and subtracting from (3), then multiplying out and gathering terms, we get—

$$n^3\left(1-\frac{1}{M}\right) - n^2 \times 3\, d_1\left(1-\frac{1}{M}\right) - n \times 3\, h\, (h-2\, d_1)$$
$$+\, h^2\, (2\, h - 3\, d_1) = 0 \quad . \quad . \qquad (4)$$

This may be solved by trial for any special case, since *n* only varies quite slowly and regularly with M and *d*.

To obtain some idea of the results this gives for practical cases, take—

$$d_1 = 0{\cdot}12\, d = 0{\cdot}107\, h$$

and—

$$M = 10\ (i.e.,\ B = 10\ b)$$

For this case, Equation (4) gives $n = 0{\cdot}88\, h$—
whence from (1) when $c = 600$—

$$t = \frac{600 \times 0{\cdot}12}{0{\cdot}88} = 82 \text{ lb./in.}^2$$

Having regard to the reduction of modulus when large stresses are reached, this is probably quite safe, and it should be noted it gives—

$$C = 0{\cdot}88\, b\, h\frac{c}{2}$$

instead of—

$$C = 0{\cdot}36\, b\, h\, \frac{c}{2}$$

when the tension in the concrete is neglected.

This is, of course, an important increase, and means that the safe shears in the tables on pp. 413 and 418 are increased by about 50 per cent.

If we take—

$$d_1 = 112\, d$$

and—

$$M = 4$$

it will be found from Equation (4) that this gives—

$$n = {\cdot}825\, h$$

whence—

$$t = 127 \text{ lb./in.}^2$$

when C = 600.

This does not give a proper factor of safety, and the designer would have the alternative of halving both *t* and *c* (and thereby the resistance to shear by inclined compression) or of providing a little top steel and calculating as in the following analysis :—

11. *Calculation of inclined compression taking tension in top steel into account.*

For nomenclature see *Fig.* 3c.

It must, of course, be remembered that the stress in the bottom steel t_1 is not determined by the strain diagram across the end section, since the bars are in tension, while the surrounding concrete is in compression.

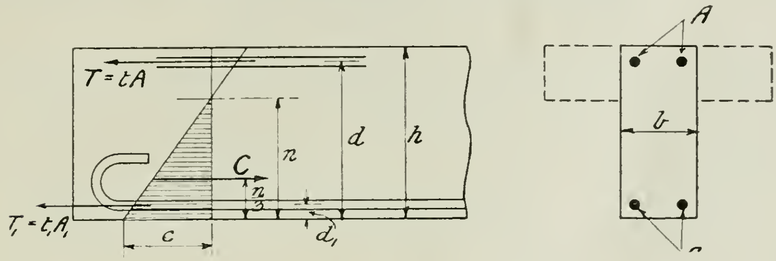


FIG. 30.
TO SHOW INCREASE OF INCLINED COMPRESSION WHEN TENSION IN TOP STEEL IS CONSIDERED.

The stress in the top steel, however, is so determined. Stress in concrete in tension is neglected.

Writing down the equations as before, we have—

$$t = 15\,c\,\frac{d-n}{n} \qquad . \quad . \quad . \quad . \quad . \qquad (1)$$

$$A\,t + A_1\,t_1 = C \qquad . \quad . \quad . \quad . \quad . \qquad (2)$$

$$A\,t\,d + A_1\,t_1\,d_1 = C\,\frac{n}{3} \qquad . \quad . \quad . \quad . \qquad (3)$$

$$C = b\,\frac{c}{2}\,n \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

Multiply (2) by d_1 and subtract from (3).

Substitute (1) and (4)—

$$A\;30\,C\left(\frac{d-n}{n}\right)(d-d_1) = b\,\frac{c}{2}\,n^2\left(\frac{n}{3}-d_1\right)$$

whence—

$$n^3 - n^2\,3\,d_1 + n\,\frac{90\,A\,(d-d_1)}{b} - d\,\frac{90\,A\,(d-d_1)}{b} = 0$$

This is a cubic equation for n which it is frequently most convenient to solve by trial.

In the special case when—

$$A = 1 \text{ per cent.} = 0{\cdot}01\;b\;d$$
$$d_1 = 0{\cdot}12\;d$$

the equation gives—

$$n = 0{\cdot}74\;d \text{ or } 0{\cdot}84\;a \text{ (when } a = 0{\cdot}88\;d)$$

(Note this gives a stress of 3,160 lb./in.^{2}.)

Then the inclined compression—

$$C = 0{\cdot}84 \times 300 \times b \times a$$
$$= 252\;b\;a$$

Assuming the centre of compression at mid-span to be $0{\cdot}12\,d$ from the top. The rise is—

$$\left(0{\cdot}88 - \frac{0{\cdot}84}{3}\right) d = 0{\cdot}6\,d = 0{\cdot}682\,a$$

Shear resisted by inclined compression

$$=252\,b\,a\times 0{\cdot}682\times\frac{a}{\frac{l}{2}}\text{ for single point loads.}$$

$$=345\,b\,a\frac{a}{l}\text{ for single point loads}=213\,\frac{b\,h^2}{l}$$

$$=690\,b\,a\frac{a}{l}\text{ for uniform loads}=426\frac{b\,h^2}{l}$$

The safe shear by inclined compression with 1 per cent. steel in top and $d_1=0{\cdot}12\,d$ is given in the following table :—

Ratio of Span to Radius Arm.	Safe Shear.	
	Concentrated Loads.	Uniform Loads.
$\frac{l}{a}$	—	—
2	23	344
3	34·5	138
10	69	69
13	172	46
20	17·2	34·5

It will noticed that this gives results about 50 per cent. higher than when neither top steel nor top concrete is taken into account (see tables on p. 413).

11*a*. *Value of* n *for maximum shear by direct inclined compression.*

The shear resisted by inclined compression is—

$$S=C\tan\theta$$

where C is its horizontal component, θ is its inclination to the horizontal.

A little consideration will show that we can increase C by taking a large value for n, but by increasing n we bring the point of application of C nearer the centre of the beam, and thus reduce θ.

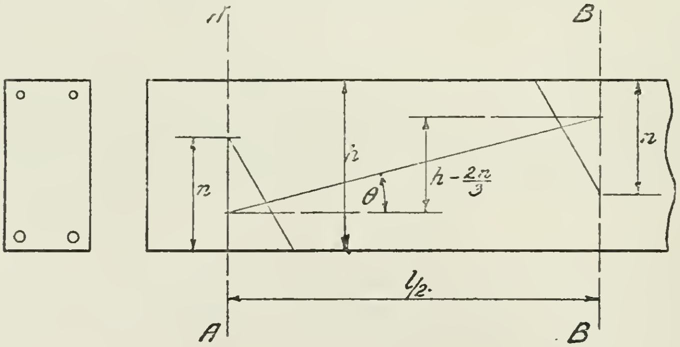


FIG. 30*a*.

A point is reached when $C\tan\theta$ is a maximum, and beyond it an increase of n involves a reduction in the safe shear resistance.

Consider a rectangular beam, with the load applied at a section $B\,B$ (*Fig.* 30*a*) and the support at the section $A\,A$, at a distance $\frac{l}{2}$ from it.

With a stress of 600 in the concrete at the lower fibre and zero at a distance n from it, the $C = b\,n\,\frac{600.}{2}$

If n is the same at sections $A\,A$ and $B\,B$, as it generally would be for rectangular sections (but not with **T** beams) we may put—

$$\tan\theta = \frac{h - \frac{2n}{3}}{\frac{l}{2}}$$

Hence the shear by inclined compression is—

$$S = b\,n\,\frac{600}{2}\,\frac{h - \frac{2n}{3}}{\frac{l}{2}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

To obtain a maximum, we will equate the differential co-efficient with regard to n to zero—

$$\frac{dS}{dn} = \frac{300\,b}{\frac{l}{2}}\left\{ h - \frac{4n}{3} \right\} = 0\,.$$

whence—

$$n = \frac{3h}{4}$$

This value gives the greatest possible resistance to shear for rectangular sections.

It is to be noted that this result agrees closely with the value obtained in section 11, where top steel is provided, and may with sufficient accuracy for most purposes be used in practice in such cases.

Substituting this value in (1) we get—

$$S = b\,.\,\tfrac{3}{4}h\,.\,300\,.\,\frac{h - \frac{h}{2}}{\frac{l}{2}}$$

$$= 225\,\frac{b\,h^2}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

This is a simple and convenient formula for practical use where steel is provided top and bottom.

Where the load is not a central point load the formula may be written—

$$S = \frac{225\,b\,h^2}{l_1}$$

where l_1 is the "point-load span," as explained.

Note that with $n = 0{\cdot}75\,h$, we have—

$$C = 0{\cdot}75 \times b \times h \times 300 \text{ lb.}$$

This acts at a distance of $0{\cdot}25\,h$ from the bottom, or $0{\cdot}25 - 0{\cdot}107 = 0{\cdot}143\,h$ from the bottom steel, and $0{\cdot}75 - 0{\cdot}107 = 0{\cdot}643\,h$ from the top steel.

Hence tension required in bottom steel—

$$T = C \times \frac{0{\cdot}643}{0{\cdot}786} = 225\,b\,h \times \frac{0{\cdot}643}{0{\cdot}786} = 184\,b\,h$$

Limiting the steel to 16,000, the area of steel required is—

$$A = \frac{184\,b\,h}{16{,}000} = 0{\cdot}0115\,b\,h, \text{ or say } 1{\cdot}2 \text{ per cent.}$$

12. *Direct inclined compressions in continuous beams.*

Consider a continuous beam with central point loads, as in *Fig.* 31.

The bending moment diagram will be as in (*c*), giving $\frac{W\,l}{8}$ at centre and support, though it would be necessary to design for greater moments than these in cases where the simultaneous action of loads in all spans could not be relied on.

In such a beam the top fibres would be in tension from support to $l/4$ each way, and the bottom fibres through the central half-span.

In practice a beam would generally be reinforced as in *Fig.* 31 (*a*)—that is, the bottom bars would be carried through to the supports, while in the top

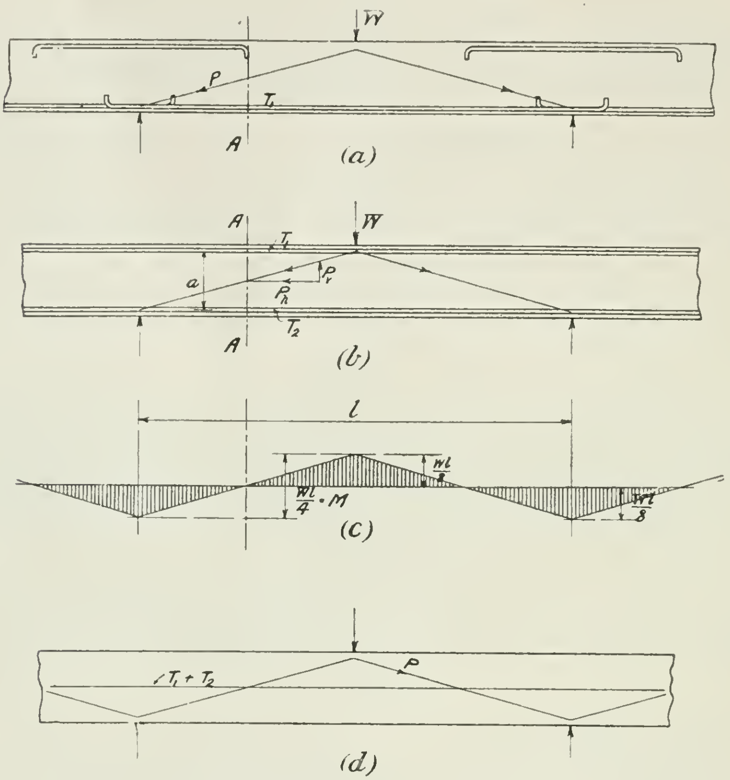


FIG. 31. INCLINED COMPRESSION IN CONTINUOUS RECTANGULAR BEAMS WITH CONCENTRATED LOAD.

reinforcement is supplied as far as the points of contraflexure only. (No double stirrups and bent bars would be used as well, but these need not be considered now.)

Consider now the forces acting across the action *A A* at the point of contraflexure.

As the moment at this point must be zero, and as there can be no tension at the top (since the steel is stopped short) it follows that either—

(1) P and T_1 intersect here, or
(2) P is zero, or
(3) T_1 is zero.

The first of these alternatives evidently does not apply. The second implies no shear resisted by inclined compression.

As regards the third, it will be seen that if we insist on true beam action (total tension equal to total compression) it implies P = zero, and therefore the same result, that no shear can be resisted by inclined compression.

If we do not insist on this condition, we are dealing with a line of continuous arches, not beams, and we will here confine ourselves to the latter.

We therefore have the following important result :—

In continuous beams, where the top reinforcement does not extend beyond the point of contraflexure, no shear may be resisted by direct inclined compressions.

This does not prevent very important resistance to shear by indirect inclined compressions. This is dealt with later.

Consider now *Fig.* 31 (*b*), showing a beam under similar conditions, but having the steel in top and bottom extended continuously through the various spans (though not necessarily without joints, provided they are well lapped and hooked, or otherwise connected).

Consider now the conditions at the point of contraflexure in such a beam, where the whole shear is to be carried by inclined compression.

Since total tension = total compression we have—

$$P_h = T_1 + T_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Since the whole shear is to be taken by the inclined compression—

$$P_v = \frac{W}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Now—

$$\frac{P_v}{P_h} = \frac{a}{\frac{l}{2}} \text{ from the figure}$$

Substituting (1) and (2)—

$$2\left(\frac{W}{T_1+T_2}\right) = \frac{a}{\frac{l}{2}}$$

whence—

$$T_1 + T_2 = \frac{W\,l}{4} \times \frac{1}{a}$$

Now $\frac{W\,l}{4}$ is the M_t the total bending moment in the beam considering the ends free.*

Hence we have the following important result :—

If in a continuous beam the whole *shear is to be taken by the inclined compression, continuous steel must be provided to take and carry a total tension equal to the total free bending moment divided by the radius arm.*

The horizontal component of the inclined compression must equal the same figure.

This means that the steel and concrete have to be just as ample as if the beam were designed as a free beam, the only change being that the steel is now partly along the top and partly along the bottom.

It would also be quite permissible to put the whole steel in the centre of the beam, as in 31 (*d*), when it will be seen that the internal moments still equal the external moments at every point.

A careful consideration of the problem will show that the formula—

$$S = 225\,\frac{b\,h^2}{l_1}$$

already derived in section 11*a* applies to continuous beams, the only difference being that the steel required—

$$A = 0{\cdot}014\,b\,h\left(=\frac{225\,b\,h}{16{,}000}\right)$$

---

* Note that $M_t = M_c + M_s$ in symmetrical arrangements, where M_c is the centre moment and M_s is the moment at the supports. In this case $M^t = \frac{W\,l}{4}$ and $M_c = M_s = \frac{W\,l}{8}$.

must be distributed between the two flanges, instead of being concentrated in the lower one.

The steel required in the bottom flange is—

$$0{\cdot}014\ b\ h \times \frac{M_c}{M_t}$$

and in the top flange is—

$$0{\cdot}014\ b\ h \times \frac{M_s}{M_t}$$

In the cases where, owing to different loadings of adjacent panels, M_c and M_s may vary, the worst case must be taken. In that case the total steel required may exceed 0·014 $b\ h$.

Thus with a uniform load—

$$M_t = \frac{W\ l}{8}$$

and if we require to design centre and support for—

$$M_c = \frac{W\ l}{12} \text{ and } M_s = \frac{W\ l}{12}$$

we have area of steel required in top—

$$= 0{\cdot}014\ b\ h \times \frac{8}{12}$$

and the same in the bottom.

This gives a total area of $0{\cdot}014\ b\ h \times \frac{16}{12} = 0{\cdot}0186\ b\ h$.

In the case of a beam where so much steel is not provided, we may use the formula—

$$S = 150\ \frac{b\ h^2}{l_1}$$

in which case the top steel required is—

$$0{\cdot}006\ b\ h \times \frac{M_s}{M_t}$$

and the bottom steel required is—

$$0{\cdot}006\ b\ h \times \frac{M_c}{M_t}$$

As a practical example of a continuous beam with considerable top and bottom steel carried right through, consider a silo wall resisting pressure from either side alternately.

Here we have—

$$M_t = \frac{W\ l}{8}$$

Suppose now we design the ends and centre for—

$$M_c = M_s = \frac{W\ l}{12}$$

and design the slab by the formula—

$$M_c = M_s = \frac{W\ l}{12} = 95\ b\ d^2 \quad . \quad . \quad . \quad . \quad (1)$$

Using 0·675 per cent. of steel on each side measured on $b\ d$.

If the distance from the *C.L.* of steel to the edge of the slab is $0{\cdot}12\ d$, as it will generally be approximately, we may put $h = 1{\cdot}12\ d$.

$95\ b\ d^2$ may be written $0{\cdot}76\ b\ h^2$ and $0{\cdot}00675\ b\ d$ may be written $0{\cdot}006\ b\ h$.

We therefore have, from (1)—

$$\frac{W\ l}{12} = 76\ b\ h^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Notice, now, that the area of steel required in each flange to justify—

$$S = 225 \frac{b\ h^2}{l_1} \text{ is } 0{\cdot}014 \times \frac{8}{12} = 0{\cdot}0093\ b\ h$$

whereas to justify—

$$S=150\frac{b\,h^2}{l_1}\text{ is }0{\cdot}006\times\frac{8}{12}=0{\cdot}04\ b\ h$$

As we are providing 0·006, which lies between these values, we may take—

$$S=\left\{150+75\times\frac{0{\cdot}2}{0{\cdot}53}\right\}\frac{b\,h^2}{l_1}\text{ or }178\frac{b\,h^2}{l_1}$$

Substituting $l_1=\frac{l}{2}$ for uniform loads—

$$b\,h^2=\frac{W\,l}{12\times76}\text{ from (2)}$$

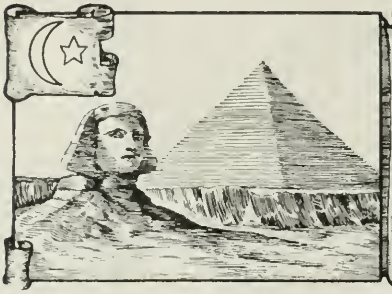
We have safe shear—

$$S=172\times2\frac{W\,l}{12\times76}=0{\cdot}39\ W\ l$$

The actual shear is, of course, 0·5 $W\,l$, so that if designed on the basis above mentioned, 0·78, or rather over $\frac{3}{4}$, of the total shear can safely be resisted by inclined compression. If the *whole* shear were resisted in this manner, it only means that the concrete will be slightly overstressed to—

$$600\times\frac{0{\cdot}5}{0{\cdot}39}=770\text{ lb./in.}^2$$

(To be continued.)



REINFORCED CONCRETE CHURCH ARCHITECTURE IN THE EAST.

THE CATHOLIC BASILICA AT HELIOPOLIS, CAIRO.

Whilst there are not many examples of reinforced concrete Church buildings in this country, this form of construction has been widely used in the East, and the following are some short particulars, together with illustrations, of a Catholic Church at Cairo.—ED.

The new town of Heliopolis until lately lacked a large Catholic church commensurate with its importance as the seat of the Archbishop of Egypt.

Thanks to a wealthy donor, this building has been erected, and the Basilica of Heliopolis forms the central place of worship of the diocese, and at the same time is large enough to accommodate the members of the church in this growing town, which, although scarcely ten years old, has a population of about 8,000 inhabitants.

The Basilica is in the Byzantine style, is built upon a square plan, with a large central dome on pendentives springing from four semicircular arches rising from piers at each corner.

These corner piers are carried up as low tower masses at each angle of the building, and are finished with small cupolas.

The choir and chancel are built projecting from the square of the church, and this portion of the building is roofed by a semicircular wagon vault terminating in a semi-dome.

In order to conform with the traditional arrangement of the Eastern Catholic Church, galleries have been formed, under the main arches carrying the central dome, on both sides and at the end of the building, and these are reserved entirely for the female worshippers.

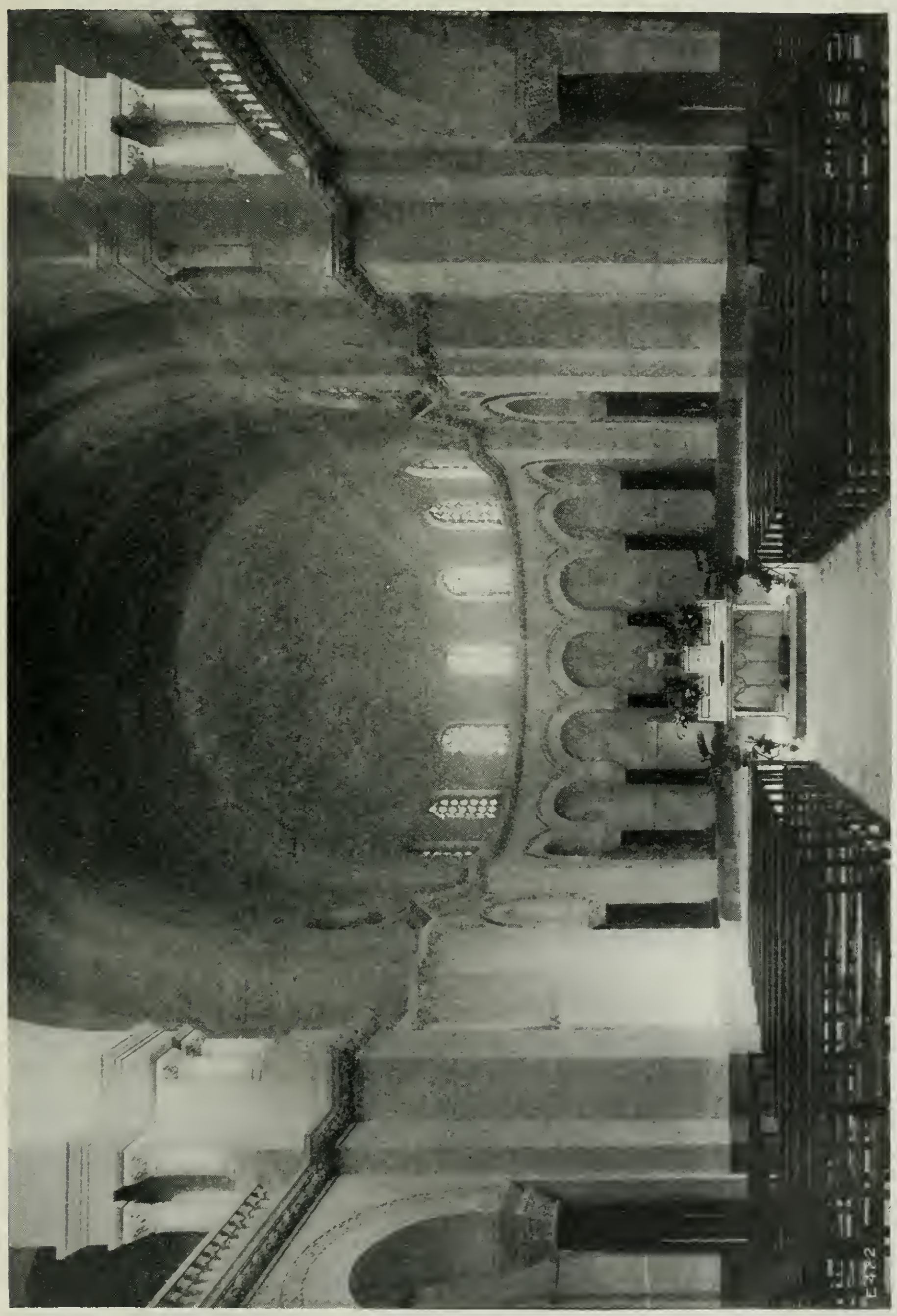
The Basilica stands on an island site at the termination of the Avenue des Pyramides, surrounded by many luxurious buildings.

As will be seen from the photographs, a porch consisting of three arches resting on double columns of red porphyry shelters the three doors giving access to the church, whilst in the centre of each side doorways are provided.

Internally the building is finished in marble and mosaic reminiscent of the Byzantine building of old Ravenna. Columns of Italian marble support the three arches carrying the galleries, and the soffites of arches and pendentives and dome are finished with brilliant mosaic work.

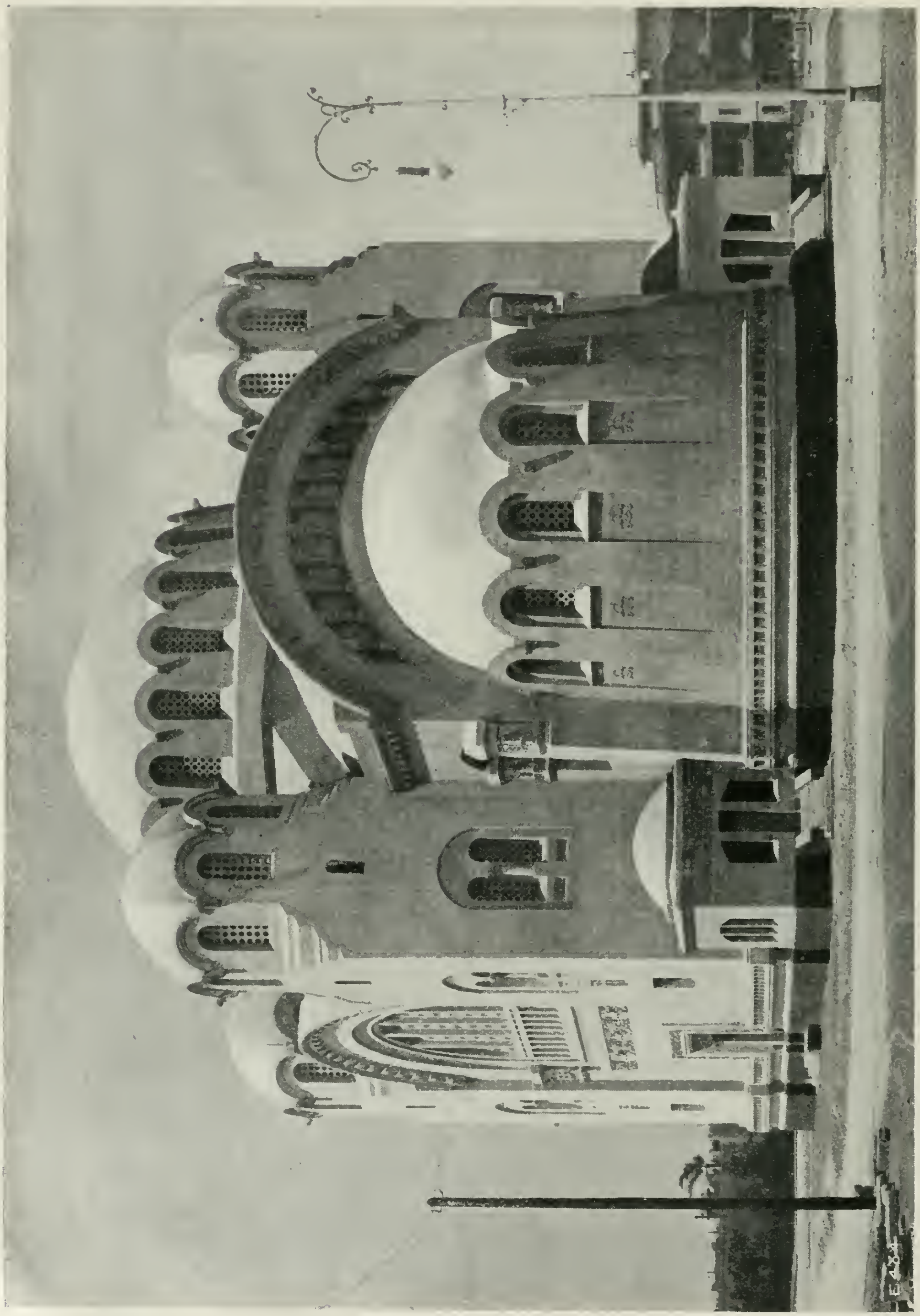
The shell of the building is entirely constructed of reinforced concrete on the Hennebique system. Externally the structure is faced with reconstructed stone.

The building, when seen silhouetted against the blue Egyptian sky, gives



Interior View

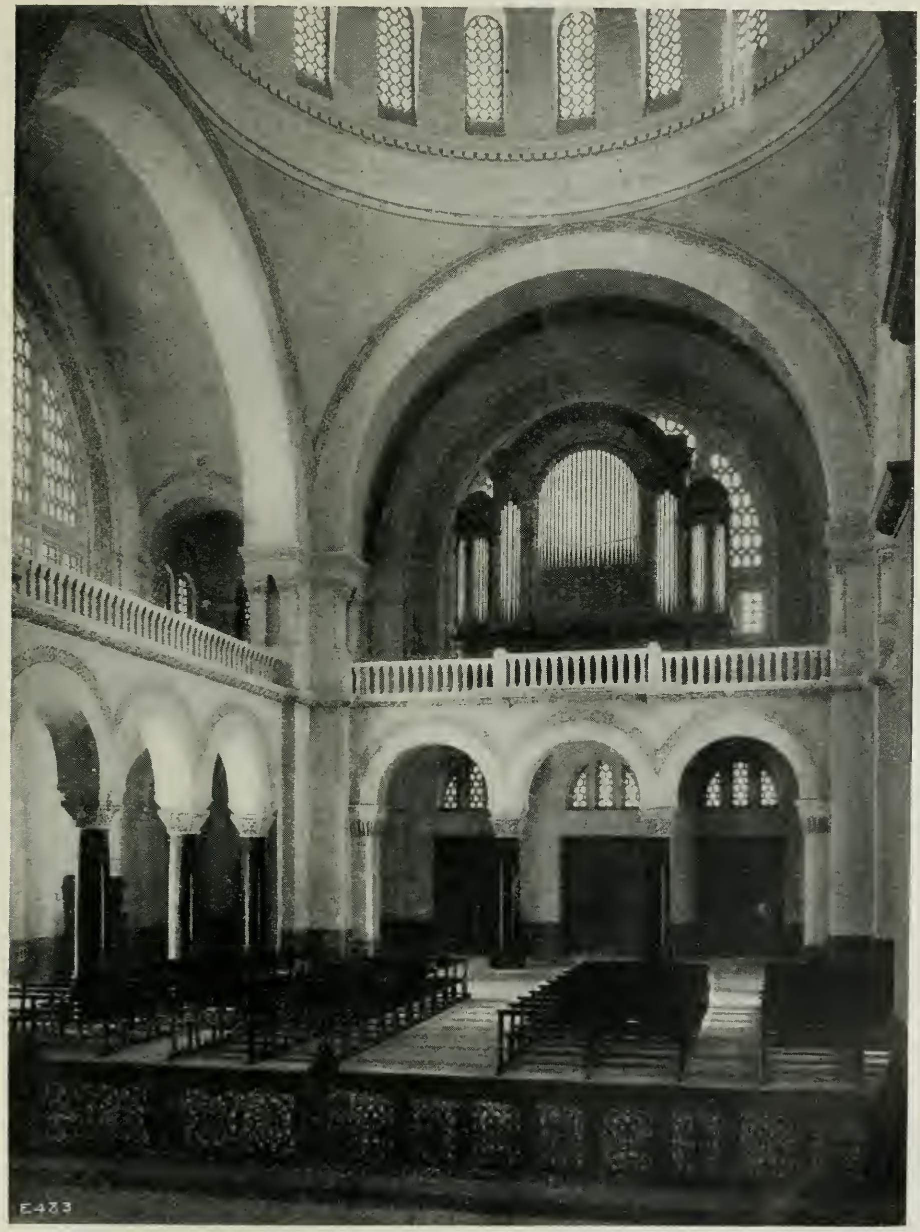
The Basilica, Heliopolis, Cairo.



An Exterior View.
THE BASILICA, HELIOPOLIS, CAIRO.

the observer the impression of solidity and grandeur that is so characteristic of the ancient constructions of the land of the Pharaohs.

The architect for the building is Mons. A. Marcel, of Paris, to whom we are indebted for these particulars and illustrations.



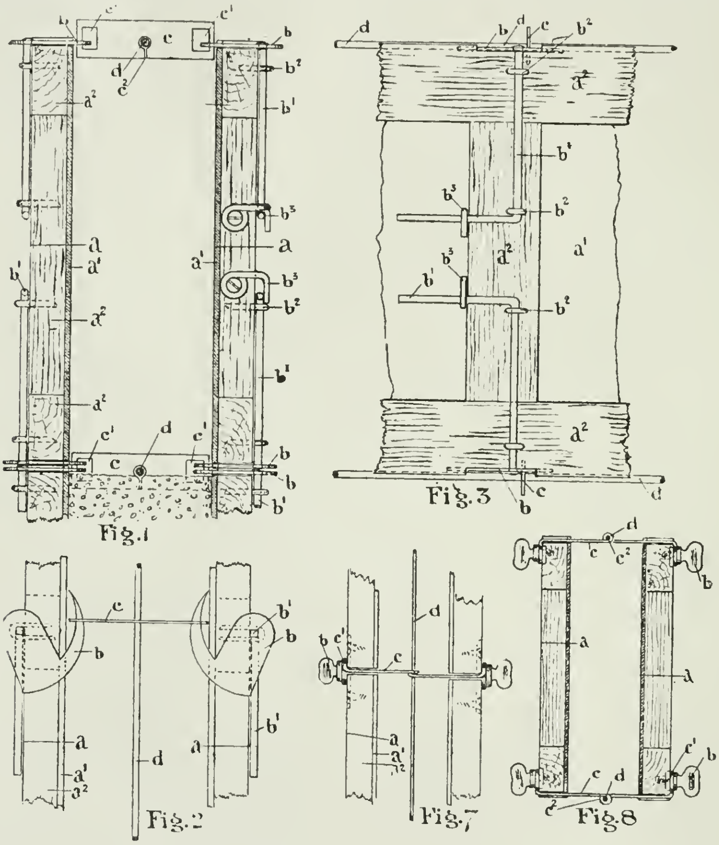
An Interior View.
THE BASILICA, HELIOPOLIS, CAIRO.

RECENT BRITISH PATENTS RELATING TO CONCRETE.

We propose to present at intervals particulars of British Patents issued in connection with concrete and reinforced concrete. The last article appeared in our issue of April, 1916.—ED.

Reinforced Concrete Walls.—*No.* 3,650/15. *C. M. Burnett, St. Katharines, Clifton Road, Shirley, Southampton. Accepted March* 8/16.—Shuttering for the construction of reinforced concrete walls is supported in accordance with this invention from the tensile reinforcement by means of loops from which the shutters can be released.

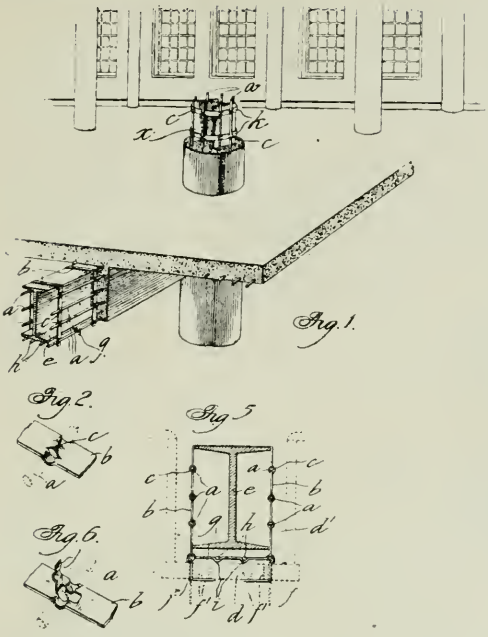
The shutters are made in standard sizes and are composed of a timber backing with a facing a^1 of iron sheet, asbestos sheet, cement, or any other suitable material.



REINFORCED CONCRETE WALLS.

The reinforcement *d* is first anchored so as to be able to support the shuttering, and sheet or wire loops *c* are passed over the reinforcement, hooks *b* carried by the shuttering being engaged with the loops which remain cast in the wall. Actuating bars b^1 for operating the hooks may be provided, cleats b^3 serving to hold them in closed position.

In a modified construction, *Figs.* 7, 8, wire loops *c* are employed and they project over the shuttering, being held releasably by thumb screws b^1.



REINFORCEMENTS FOR GIRDER AND COLUMN CASING.

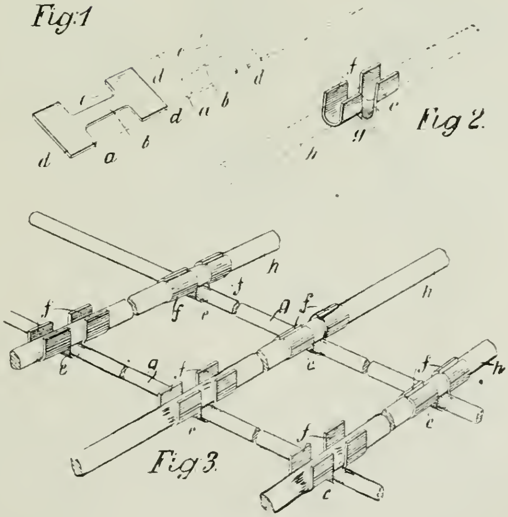
Reinforcement for Girder and Column Casing.—*No.* 4,756/15. *K. M. Concrete Steel Co., National Mutual Buildings, Melbourne, Australia. Accepted March* 27/16.—According to this invention, reinforcing rods *a* for the casing of rolled steel girders are supported by straps *b* which support also a centering board *d* for the bottom of the mould.

The reinforcing bars pass through loops *c* in the straps, these loops being conveniently stamped by dies and so arranged that the centres of the bars lie in the same plane as the straps. In practice the straps are first placed on the strap and the bars are then threaded through, thus forming a mesh reinforcement which is then placed centrally on the girder and the ends bent over, the extreme ends being passed through the centering board, bent over and secured by nails f^1. Cross bands *g* supporting rods *h* are secured across between the straps to provide the bottom reinforcement.

Fig. 1 shows also the use of the mesh formed of the straps and longitudinal bars to form a fabric for steel column casings.

Fastening Clips for Reinforcement.—*No.* 4,803/15. *K. M. Concrete Steel Co., National Mutual Buildings, Melbourne, Australia. Accepted March* 27/16.—A clip for fastening two bars at an angle to each other is formed according to this invention from a blank of H or T shape, one portion being bent to form a loop in one direction and the other to form a loop at an angle, the essential feature being that the end parts of the portion *b* being made wider than the centre portion.

The blank *a* is shaped in dies to form the loops *e*, *f*, and when placed over the bars to be joined the ends are bent over tightly as shown.



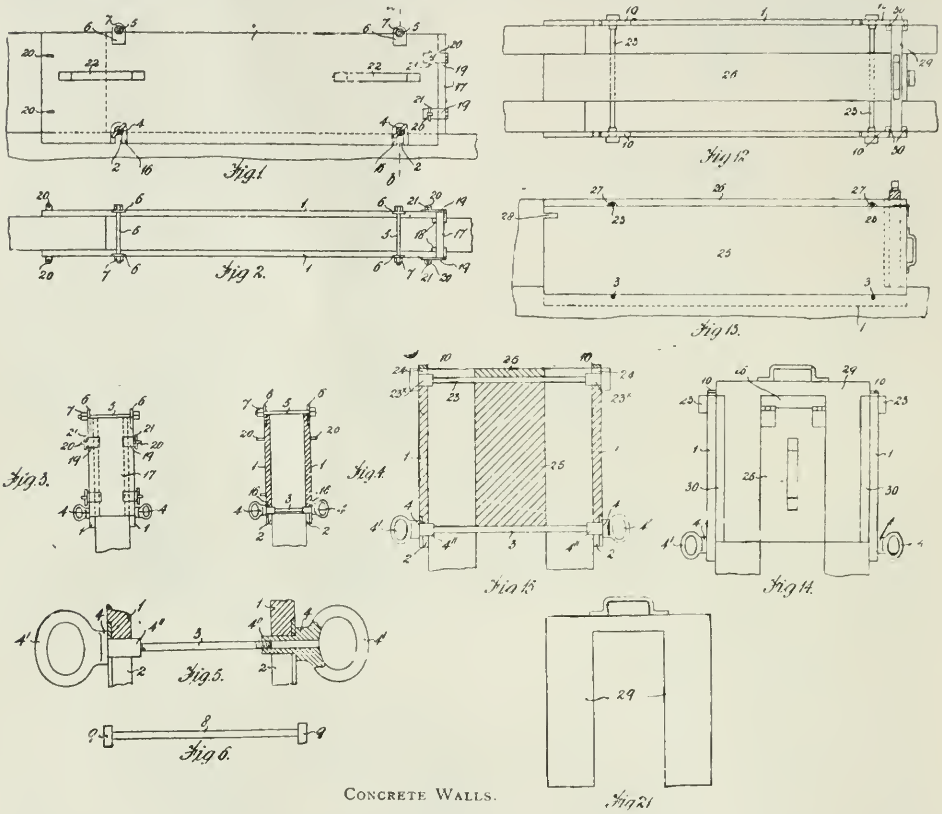
FASTENING CLIPS.

Concrete Walls.—*No.* 7,707/15. *W. Calway, 1, Hartington Park, Redland, Bristol. Accepted May* 22/16.—This invention comprises improvements in shuttering for concrete walls.

For non-cavity walls, the shutters 1, *Figs.* 1-4, are formed at their bottoms with two or more open slots 2 and are connected at their bottoms by screwed rods 3 and shouldered nuts 4, formed with wings or loops. These screwed rods are flattened in places or otherwise arranged to prevent their rotation in the concrete when their nuts are removed; the nuts, *Fig.* 5, have smooth hubs 4 in. in front of their shoulders and make close fits in the open slots 2 in the shutters. The latter are connected at their tops by any suitable means such as bolts 5 passing through eyes in plates 6.

The end gate consists of a board 17 adapted to bear against the vertical end edges of the shutters, and provided on its inner face with fillets 18 adapted to bear against the inner faces of the shutter ends. These gates are secured by suitable means such as hasps 19 and staples 20.

For cavity walls, the tops of the shutters 1 are connected by similar means as previously described, and a core 25, *Figs.* 12-15, is employed which is preferably withdrawn horizontally; the core consists of a main part 25 and upper strip 26 which is hinged to the main portion and is provided at its bottom with open slots 27 for the reception of the central parts of screwed rods 3, 23^x on the central parts of corresponding solid bars 23.



CONCRETE WALLS.

Similar end gates may be employed, but if desired it may be replaced by the crutch-shaped gate shown in *Fig.* 21 which is adapted to bestride the core and to be held in place by means of fillets secured to the inner faces of the shutters.

When a non-cavity wall has central reinforcement, a special end-gate with a gap to take the reinforcement may be employed.

Centering for Domes.—*No.* 5,227/15. *F. Thackeray, 3, Cambrian Terrace, Gwaelodygarth Road, Merthyr Tydfil, Wales. Accepted April 6/16.*—This invention comprises an improved construction of templet for concrete domes, the templet being connected by a shaft capable of swivelling in any plane, the arrangement being such that a small templet may be employed and moved readily from one position to another as the work proceeds.

The templet *A* is connected by a lock-nut *E* to a shaft *B* which is mounted on a ball-joint formed on a central pillar *C*, *Fig.* 1, or else is connected by an eye-bolt *G*, *Fig.* 1a, to a pin *Y* capable of rotation in a hollow pillar *Z*. Stays *F* are provided for the templet.

The arrangement shown in *Fig.* 1 is suitable for a spherical dome; for a dome struck from three centres the modified constructions shown in *Figs.* 9-14 may be employed. The dome above the dotted line *R* is made up of curves with a common centre and is carried out by means of the ball-joint construction previously described. The portion *C* of the centre pillar is removable and is then replaced by a turning bracket C^2, *Fig.* 11; this bracket is used with a templet A^5 which is shaped with centre at the pivot between the shaft B^2 and bracket C^2.

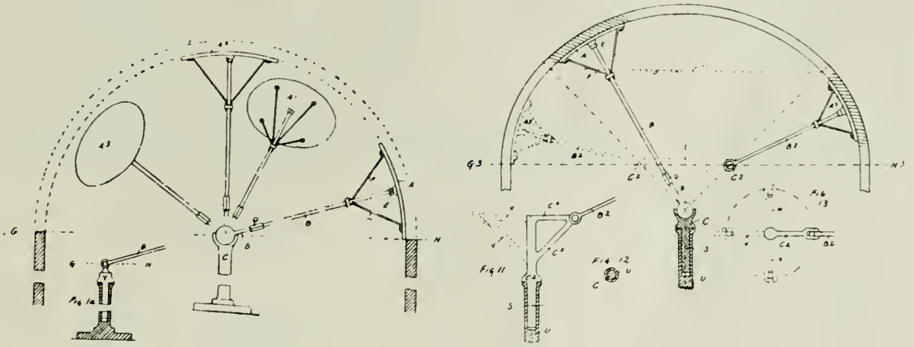


Fig. 1.

Fig. 9.

Centering for Domes

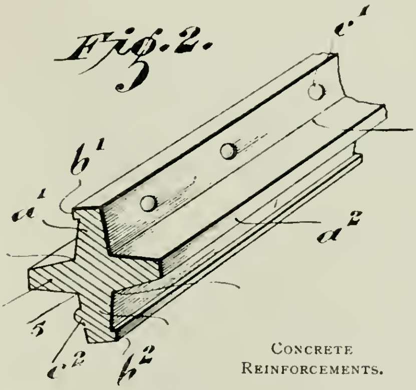
Fig. 13 shows four positions of the bracket C^2 during its turning movements; in a modification the bracket may have four arms, or three as in *Fig.* 14, a curved templet being hinged about each.

Concrete Reinforcement.—*No.* 5,660/15. *A. R. Banks, Churchfield, West Bromwich, and A. Bye,* 298, *High Street, West Bromwich. Accepted March* 23/16.—Concrete reinforcement in accordance with this invention is of cruciform section, and one or more flanges a^1, a^3 is provided with a projecting lip b^1, b^2 on one side only.

These lips are preferably formed on the upper and lower vertical flanges and face in opposite directions as shown.

The adhesion of the bars may be further increased by projecting bosses c^1, c^2 formed on the reverse faces of the flanges a^1 a^3.

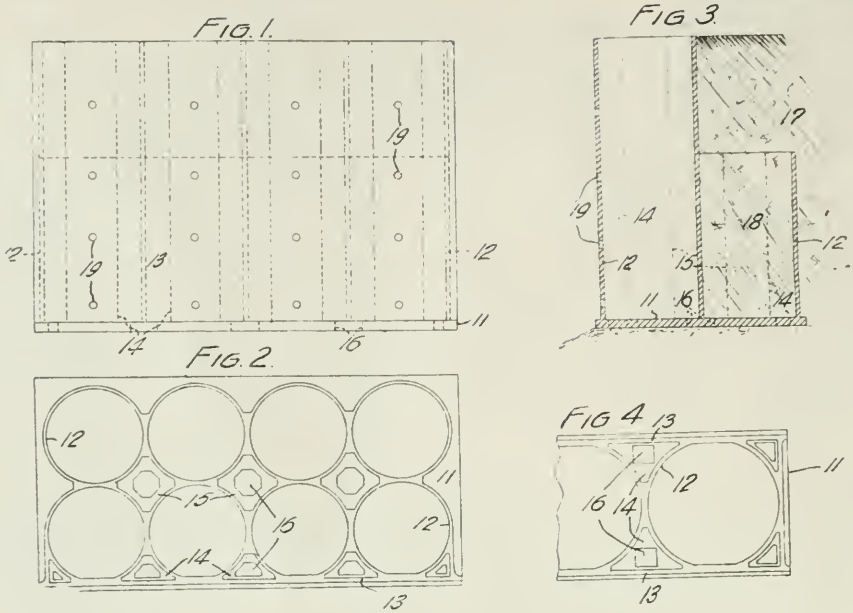
Fig. 2.



Concrete Reinforcements.

Concrete Caissons.—*No.* 7,445/15. *J. Spelman,* 189, *St. James Street, Montreal, Canada. Accepted March* 2/16.—According to this invention a concrete caisson is made of one or more cylindrical cells which are arranged axially vertical on a heavy base. The caisson is provided on the seaward side with a straight wall tangential to the cylinders. This wall forms with the cylinders substantially triangular spaces which communicate with the water apertures formed in the base; the inner row of cylinders is, for economy of material, formed lower than the outer, only the inner row being filled, suitable entrances for water being provided in the outer row. This keeps the centre of gravity well back from the geometric centre so that increased toe pressure and tilting of the structure are prevented.

The cylinders 12 are formed integral with the base 11, which closes the ends of the cylinders and forms a cellular structure. A tangent wall 13 is formed integral with the base and cylinders at one or both sides. To increase the crushing resistance, apertures 16 are formed through the base communicating with the cells 14, 15 so as to increase the surface exposed to the water pressure when floated.



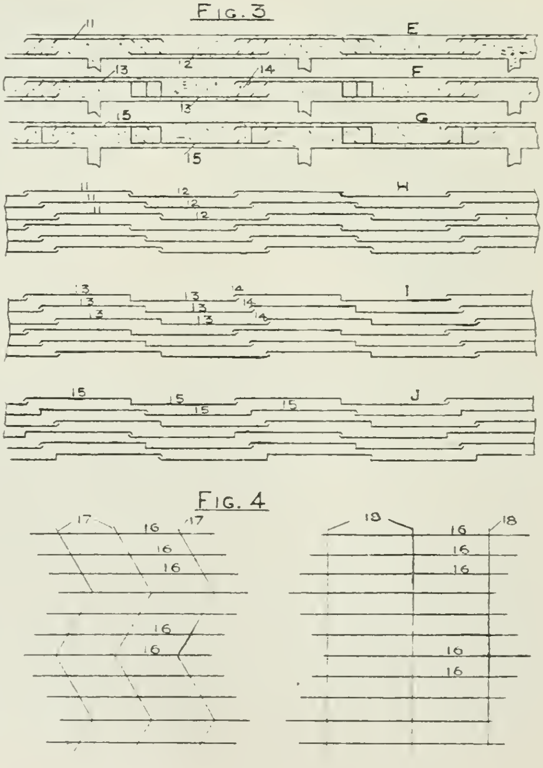
Concrete Caissons.

Fig. 3 shows the construction with the inner row lower than the outer cylinders; the outer row remains partly filled in or unfilled after the structure is in place and has apertures 19 for the admission of water to the cells.

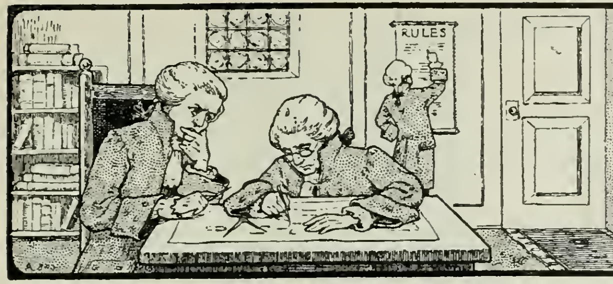
Arrangement of Concrete Reinforcement. — *No.* 6,319/15. *J. A. Davenport*, 13, *Harrington Street, Liverpool. Accepted April* 28/16.—According to this invention, the reinforcing bars are arranged in a staggered manner, thus allowing a large number of bars of the same length to be employed while securing the requisite grouping of bars according to the variation in the bending moment. The invention is an improvement upon those of 4,231/12 and 17,729/11.

Fig. 3 illustrates the staggered arrangement in beam construction, and *Fig.* 4 shows a mesh reinforcement with the bars staggered.

The staggered arrangement of reinforcement may be employed in conjunction with hollow spaces or light-weight cores in the concrete at the places where the stresses are small.



Arrangement of Concrete Reinforcement.



PERCENTAGE REINFORCEMENT DIAGRAM FOR REINFORCED CONCRETE BEAMS.

By **EWART S. ANDREWS, B.Sc.**

It is believed that the following diagram will be of considerable assistance to readers who have reinforced concrete beams to design.—ED.

THE diagram on the following page will be found to save time in finding the necessary area of reinforcement for a beam of given depth and breadth when the percentage reinforcement is given.

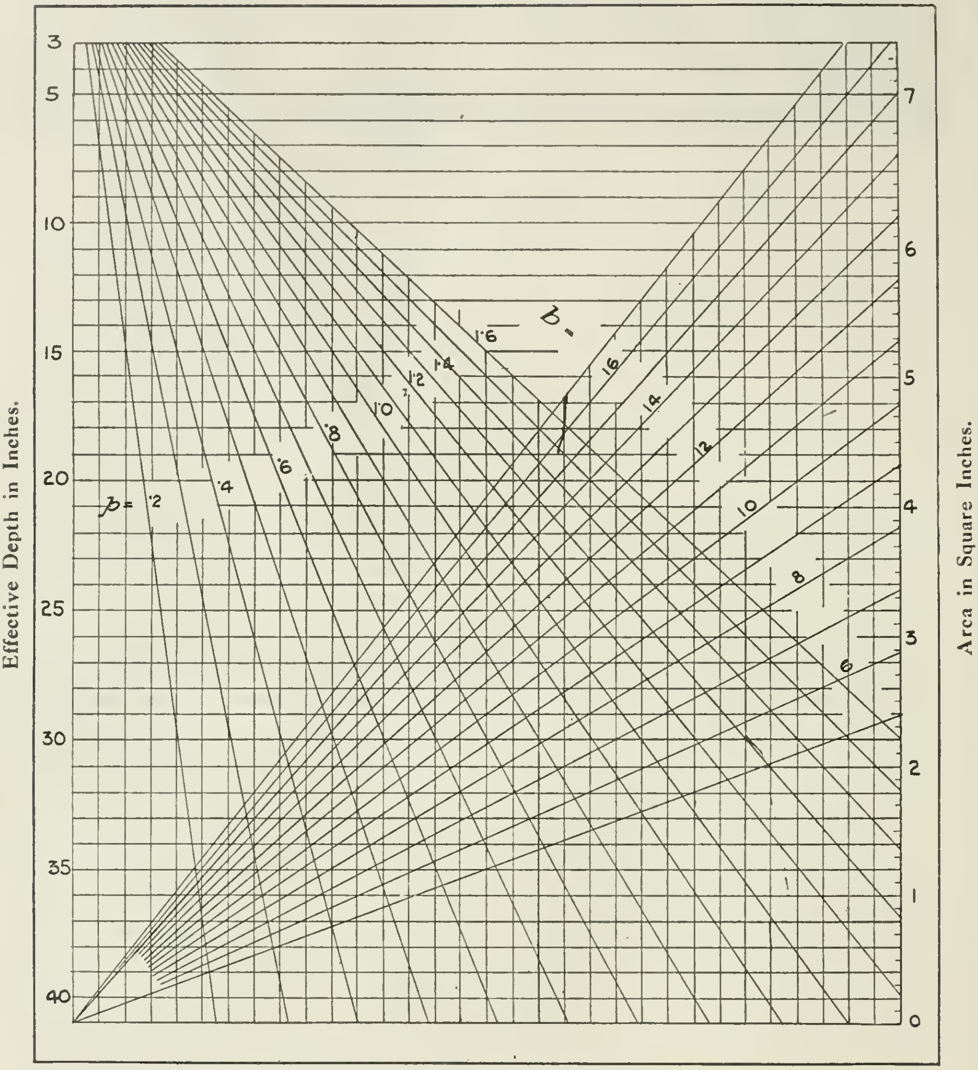
In calculations for reinforced concrete beams, diagrams giving the necessary percentage reinforcement for given values of $\frac{B}{b\,d^2}$ are often employed, B being the bending moment in pound-inch units, b the breadth and d the effective depth of the beam in inches. The quantity $\frac{B}{b\,d^2}$ is commonly called the " Resistance Modulus " of the beam, and is called the " Qualifier Q " in the London County Council Regulations, and diagrams giving the percentage reinforcement, p, required for various values of the Resistance Modulus are given in the leading text-books upon the subject.

To use the diagram we find the point corresponding to the depth on the left-hand side of the diagram and move horizontally until we meet the inclined line corresponding to the given percentage reinforcement, p. We then move vertically until we meet the inclined line corresponding to the given breadth, and then move horizontally and read off the necessary area on the right-hand side.

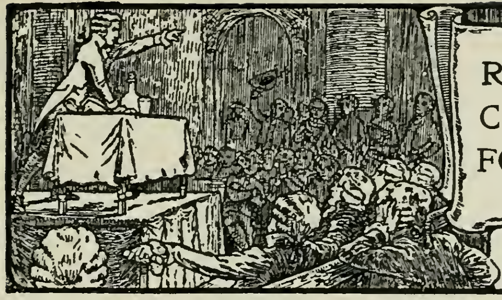
Taking, for instance, $d = 22$, $p = {}^{\cdot}85$, and $d = 10$, we read $A = 1{\cdot}87$.

This diagram can conveniently be employed in connection with the following table of areas of grouped bars from $\frac{3}{8}$ in. to $1\frac{1}{4}$ in. within the range of the diagram :

Number of Bars.						Diameter of Bars (inches).	Number of Bars.					
1	2	3	4	5	6		7	8	9	10	11	12
·110	·220	·331	·441	·552	·662	$\frac{3}{8}$	772	·883	·993	1·10	1·21	1·32
·196	·392	·588	·785	·981	1·18	$\frac{1}{2}$	1·37	1·57	1·77	1·96	2·16	2·35
·306	·613	·920	1·23	1·53	1·84	$\frac{5}{8}$	2·15	2·15	2·76	3·07	3·37	3·68
·441	·883	1·32	1·77	2.21	2·65	$\frac{3}{4}$	3·09	3 53	3·98	4·42	4·86	5·30
·601	1·20	1·80	2 40	3·01	3·61	$\frac{7}{8}$	4·21	4·81	5·41	6·01	6·61	7·21
·785	1·57	2·36	3·14	3·93	4·71	1	5·50	6·28	7·07			
·994	1·99	2·98	3·98	4·97	5·96	$1\frac{1}{8}$	6·96					
1·23	2·45	3·68	4·91	6·14	7·36	$1\frac{1}{4}$						



Percentage Reinforcement Diagram.



RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

AMERICAN WATERWORKS ASSOCIATION.

WATERWORKS RESERVOIRS.

By DABNEY H. MAURY.

The following is part of an abstract from a paper published in the "Journal of the American Waterworks Association," Vol. 3, No. 2:—

AFTER referring briefly to the several classes of waterworks reservoirs and explaining their respective uses and limitations, the value of the proper location of reservoirs, the author discusses the governing considerations in reservoir design, some of the difficulties encountered in actual construction, and concludes by giving some suggestions born of experience, which may help others to overcome these difficulties.

GOVERNING CONDITIONS IN RESERVOIR DESIGN.

Among the first points to be determined are the location, capacity, and elevation desired. These having been at least approximately determined, the work of designing may be begun.

On the principle that one cannot have too much of a good thing, the capacity of the reservoir should be made as large as the finances of the local water department will permit. In any event, however, the reservoir should be made large enough to tide over the demand of the four or five hours of maximum consumption, and, if possible, its capacity should at least be equal to a full day's pumpage.

The elevation would be influenced by a number of conditions, the chief among which would be the topography of the city and the height and character of the buildings to be served. If pressure is increased during fires, it may often be found advisable to instal an electric driven booster pump taking its water from the reservoir and pumping into the mains, the pump to be started when the fire alarm is turned in.

Generally speaking, where the elevation required is high and the capacity small, the reservoir will be an elevated tank supported by a tower, the whole structure usually being of steel. Other things being equal, that type of tank in which the average elevation of the stored water is highest is to be preferred; and when such tanks can be secured, as at present, at relatively low cost and in safe and attractive designs, it would seem that the old-fashioned tall standpipe in which three-fourths of the contained water served no useful purpose except to support the remaining upper one-fourth, has no longer any right to exist. Where larger capacities are required, and where the flowline of the reservoir does not have to be far above the surface of the ground, the choice in most cases naturally falls on reinforced concrete as the material for the reservoir.

One point which frequently has to be decided is whether or not the reservoir shall be covered. One advantage of covering the reservoir is that the water is more easily protected against pollution, although it is usually possible so to fence and otherwise safeguard an open reservoir that the danger of pollution from the outside is almost negligible. Another minor advantage is that the roof will keep the temperature of the stored water more uniform, and prevent ice in winter and overheating in summer.

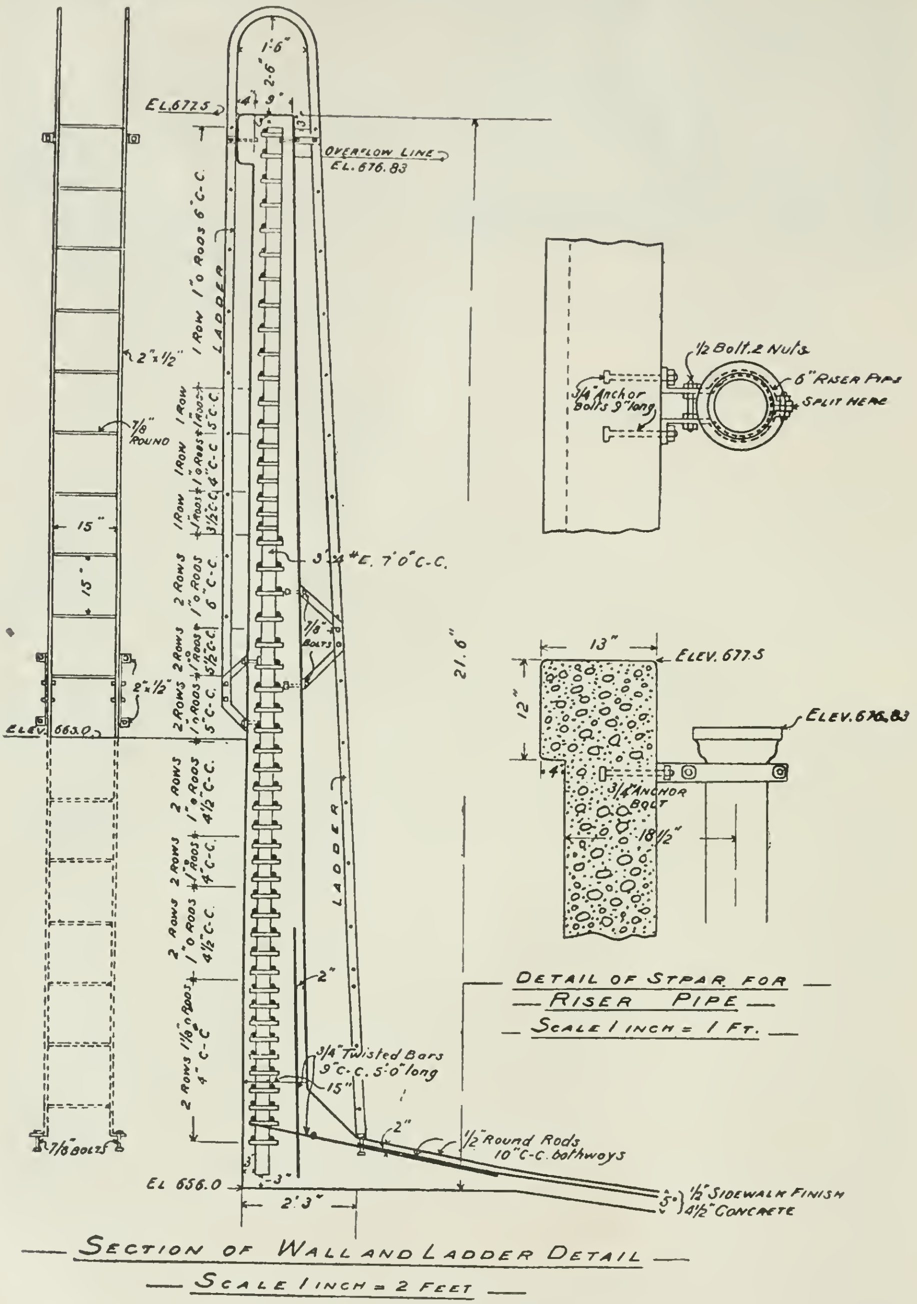


Fig. 1. Wall of 2,000,000-gallon Reservoir

Waterworks Reservoirs

Perhaps, however, the best service rendered by the roof would be the prevention of algæ by the exclusion of the rays of the sun from the water. As it is possible at small expense and with the exercise of intelligent care to stop the growth of algæ by the use of sulphate of copper, and as the addition of a roof almost always adds very greatly to the cost of a reservoir, most reservoirs, and especially those of large capacity, are of the open type.

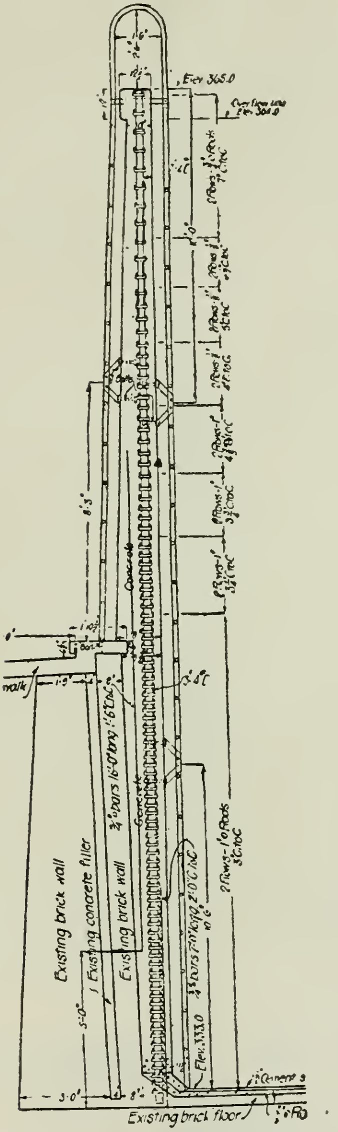


Fig. 2. Wall Section—old reservoir.

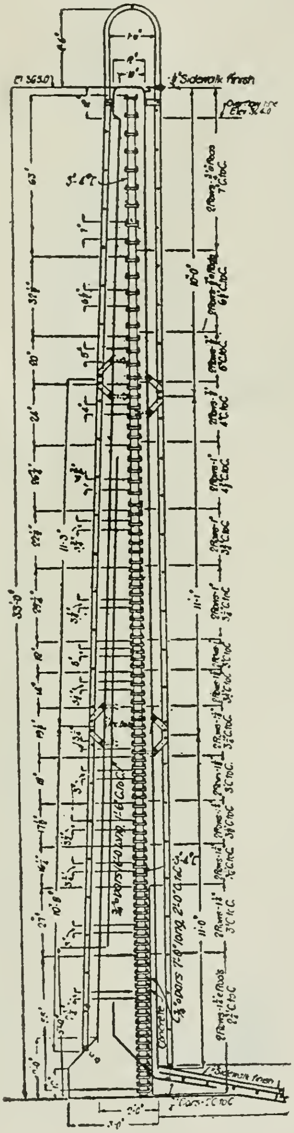
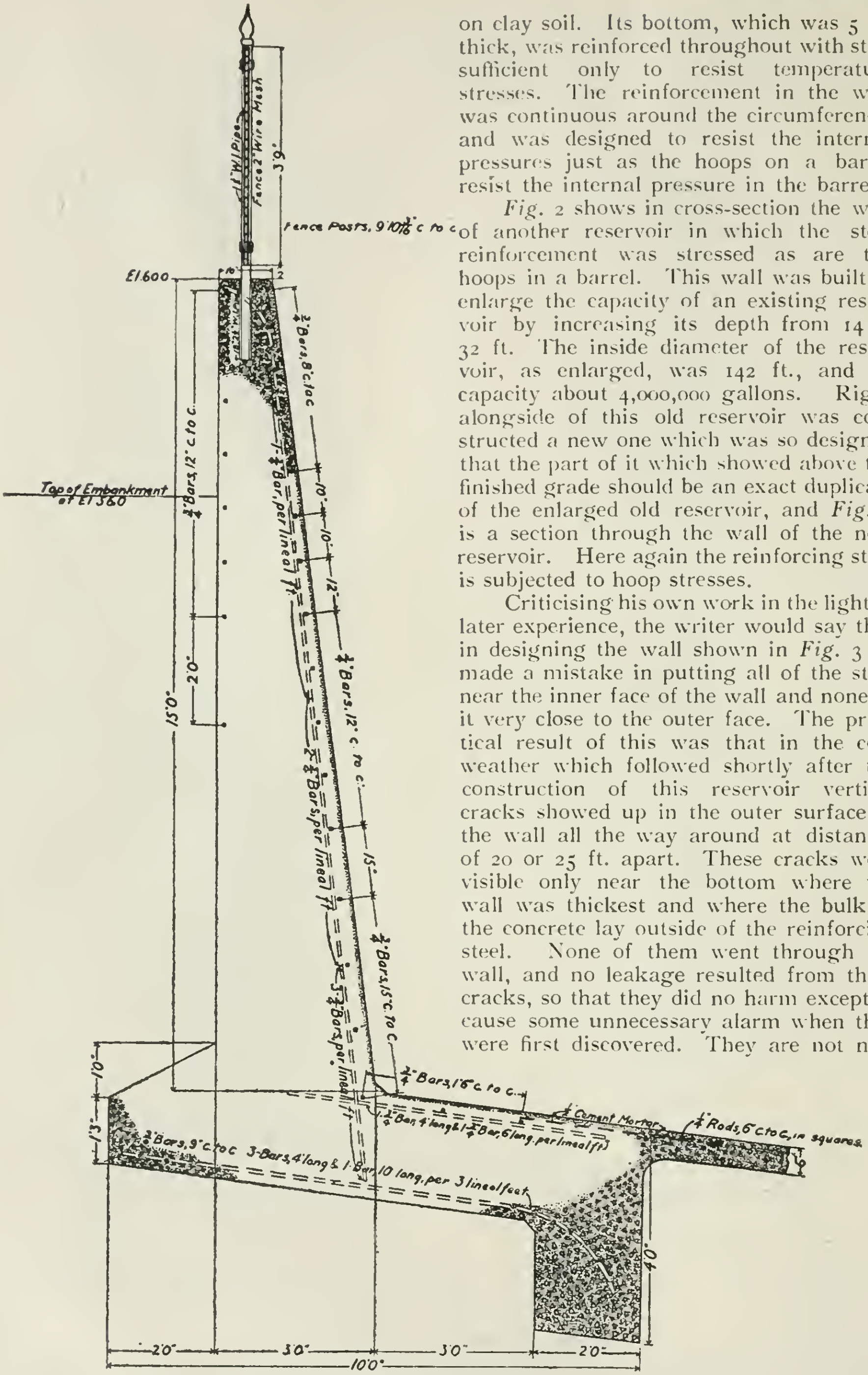


Fig. 3. Wall Section – new reservoir.

Waterworks Reservoirs.

SOME TYPICAL DESIGNS.

Fig. 1 shows in cross-section the wall and part of the bottom of a 2,000,000 gallon reservoir, 120 ft. inside diameter, 19 ft. 10 in. deep at the wall, and 24 ft. 10 in. deep at the centre. This reservoir was built partly in excavation and partly in embankment



on clay soil. Its bottom, which was 5 in. thick, was reinforced throughout with steel sufficient only to resist temperature stresses. The reinforcement in the wall was continuous around the circumference, and was designed to resist the internal pressures just as the hoops on a barrel resist the internal pressure in the barrel.

Fig. 2 shows in cross-section the wall of another reservoir in which the steel reinforcement was stressed as are the hoops in a barrel. This wall was built to enlarge the capacity of an existing reservoir by increasing its depth from 14 to 32 ft. The inside diameter of the reservoir, as enlarged, was 142 ft., and its capacity about 4,000,000 gallons. Right alongside of this old reservoir was constructed a new one which was so designed that the part of it which showed above the finished grade should be an exact duplicate of the enlarged old reservoir, and *Fig.* 3 is a section through the wall of the new reservoir. Here again the reinforcing steel is subjected to hoop stresses.

Criticising his own work in the light of later experience, the writer would say that in designing the wall shown in *Fig.* 3 he made a mistake in putting all of the steel near the inner face of the wall and none of it very close to the outer face. The practical result of this was that in the cold weather which followed shortly after the construction of this reservoir vertical cracks showed up in the outer surface of the wall all the way around at distances of 20 or 25 ft. apart. These cracks were visible only near the bottom where the wall was thickest and where the bulk of the concrete lay outside of the reinforcing steel. None of them went through the wall, and no leakage resulted from these cracks, so that they did no harm except to cause some unnecessary alarm when they were first discovered. They are not now

Fig. 4. Wall of 10,000,000-gallon Reservoir.

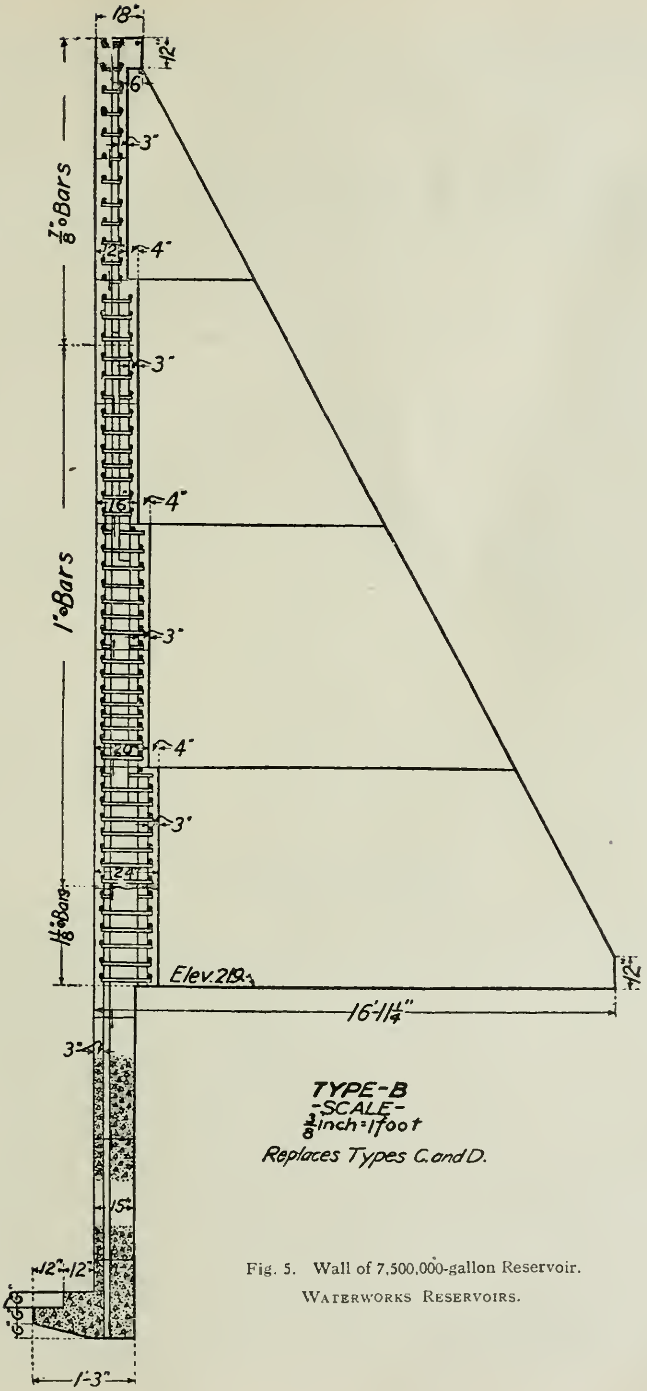


Fig. 5. Wall of 7,500,000-gallon Reservoir.
Waterworks Reservoirs.

in evidence, as the earth embankment around the reservoir covers the lower fourteen feet of its height.

Fig. 4 is a section through the wall of a reservoir of 10,000,000 gallons capacity. The diameter of this reservoir is 300 ft., and its depth at the wall 15 ft., and at the centre 25 ft. The bottom is reinforced throughout to resist temperature stresses, and the wall is designed as a cantilever gravity section, with only enough steel around the circumference to resist temperature stresses. This reservoir is believed to be the largest reinforced concrete reservoir ever built without expansion joints. It was built in 100 days, and was practically watertight when finished.

Fig. 5 is a section through the wall of a 7,500,000-gallon reservoir built almost wholly in excavation, a considerable portion of the excavation being stratified limestone rock. The diameter of this reservoir was 180 ft., and its depth 42 ft. In this case the lower part of the wall was thin and was built solidly against the rock, while that portion of the wall above the rock was constructed as a continuous slab supported by buttresses carried down to the rock, the height of the thick portion of the wall and the height of the buttresses varying with the elevation of the upper surface of the solid rock.

It will be noted that in the first three cases shown the reinforcing steel was stressed hoop-fashion, but that in the larger reservoirs of 10,000,000 and 7,500,000 gallons capacity, respectively, the hoop method was not used.

While no definite line can be drawn, it is thought that the 4,000,000-gallon reservoirs, which were 142 ft. in diameter by 32 ft. deep, were fairly close to the limit of size in which the hoop method of reinforcing could be economically employed. For capacities greater than these, the amount of steel required per vertical foot of wall becomes excessive, and usually some other type of wall will be found more economical for the larger reservoirs.

(*To be continued.*)

MEMORANDUM.

Concrete Roads —At the Annual Meeting of the Institution of Municipal and County Engineers a paper was read by Mr. T. W. Arnall, City Engineer, Birmingham, on the destruction of a macadam road. Following the paper a discussion took place in which Mr. Matthew Jones, City Engineer of Chester, said that he had constructed some reinforced concrete roads. He had brought the reinforced concrete up to the surface for the traffic to travel over, and he was quite convinced that every road must be bound with some material that was going to keep the granite in its position. With concrete roads he had made he had to keep the roads closed for three weeks or a month, according to the weather conditions, to allow the road to set thoroughly. That was the great drawback at the present time, but there was no doubt that concrete roads would come into use in this country. They stood the wear of traffic very much better than tar-macadam. The whole thing was put together as one mass, and, so far as he could see, there was not the slightest movement whatever. In a tar-macadam road they still got movement because they had got weather conditions, rain and snow to contend with. A concrete road became impervious if they allowed it to set properly. If they once got a concrete road set, they might take it from him that they had got an excellent road. If they tar-sprayed the surface and spread with granite chippings after it was set, they went still further to make it impervious to weather. There were no pot-holes in the road which he constructed four years ago. There was no brushing, or very little, required, because when the rain came down it washed the road clean.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

NEW REINFORCED CONCRETE BRIDGE IN CUMBERLAND.

THE new Esk Bridge, on the road from Carlisle to Gretna Green, was officially opened in May. It has been designed by the County Surveyor and Bridgemaster, Mr. W. Finch, on the Mouchel-Hennebique system of reinforced concrete, and replaces the old metal bridge on this road.

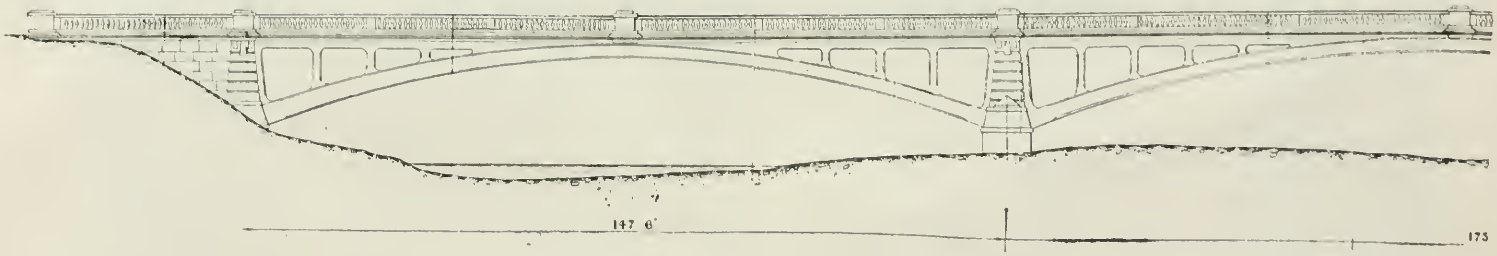
The site of the old bridge can only now be traced by the meagre remains of the abutments and piers on the east side of the new structure, and its absence severs a much vaunted connection with an historical past. The Pot Metal Bridge, as it was at one time called, was built in 1820 by Thomas Telford, and was an early venture at bridge making with cast iron. It was one of the first of its kind in the country, and was at that time considered an excellent engineering achievement. For nearly a century this bridge, quaint though it was, served as an important connection between England and Scotland, and carried the West Coast Great North Road across the river Esk into the debatable ground of the Borders. Our illustrations show the plan, part elevation, and a cross-section of the bridge.

The old bridge consisted of three spans, the southern one being 150 ft. and the two others 105 ft. in length. The gradients of the roadway over the bridge varied from 1 in 14 to 1 in 40, and this in itself, together with the narrowness of the carriageway, made it extremely dangerous for the passage of present-day traffic.

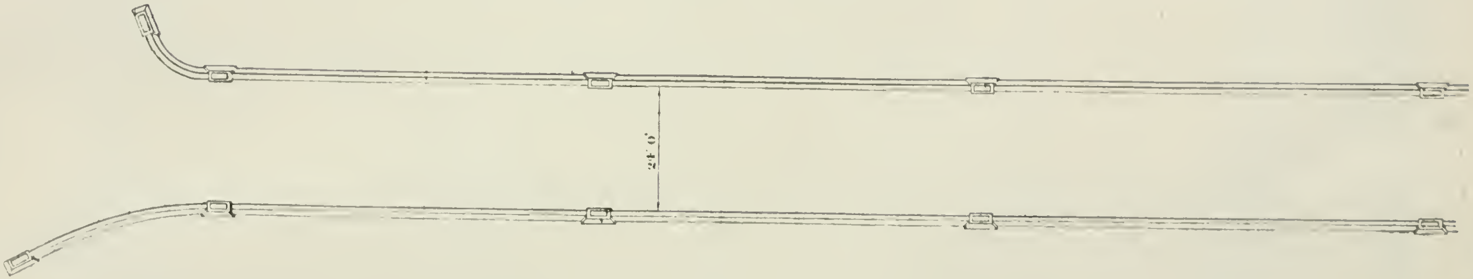
The new bridge, though not elaborate in construction, has a graceful appearance, and is devoid of unseemly masonry. The only ornamentation is the chamfering of the arch ribs and the architectural treatment of the parapets and piers. It consists of three arch spans over the river, with two short girder span flood openings in the north approach. The central arch span, which is the largest single span yet constructed under that system in the country, is 175 ft. from centre to centre of piers, giving a clear span of 165 ft., with a rise of 15 ft. The two shore spans are each 138 ft. 6 in. clear, while the flood arches have each a span of 30 ft. The foundations of the abutments and piers rest on freestone rock, with about an average of 12 ft. below the springing level. The width of the carriageway over the bridge between the parapets is 24 ft. The bridge has been designed to carry a moving load of 64 tons distributed over four axles, which, it was considered, would meet the requirements of any traffic that might pass over it.

The work was commenced in July, 1914, and completed in April, 1916, at a cost of something like £17,000.

In the course of a statement at the opening ceremony, the County Surveyor mentioned that the Local Government Board sanctioned a loan of £14,000 for the bridge for fifteen years, and £2,000 for the approaches and road works for a period of twenty years, and he was pleased to say that the cost of the work would not exceed the amount of the contract. He also mentioned that there were several reinforced concrete bridges of this type in existence throughout the country, and over 2,000 such bridges with varying spans had been constructed during the past twenty years. On account of its strength they were able to carry one of the main trunk roads of the country over the river in three spans, which would not have been possible with any form of masonry.

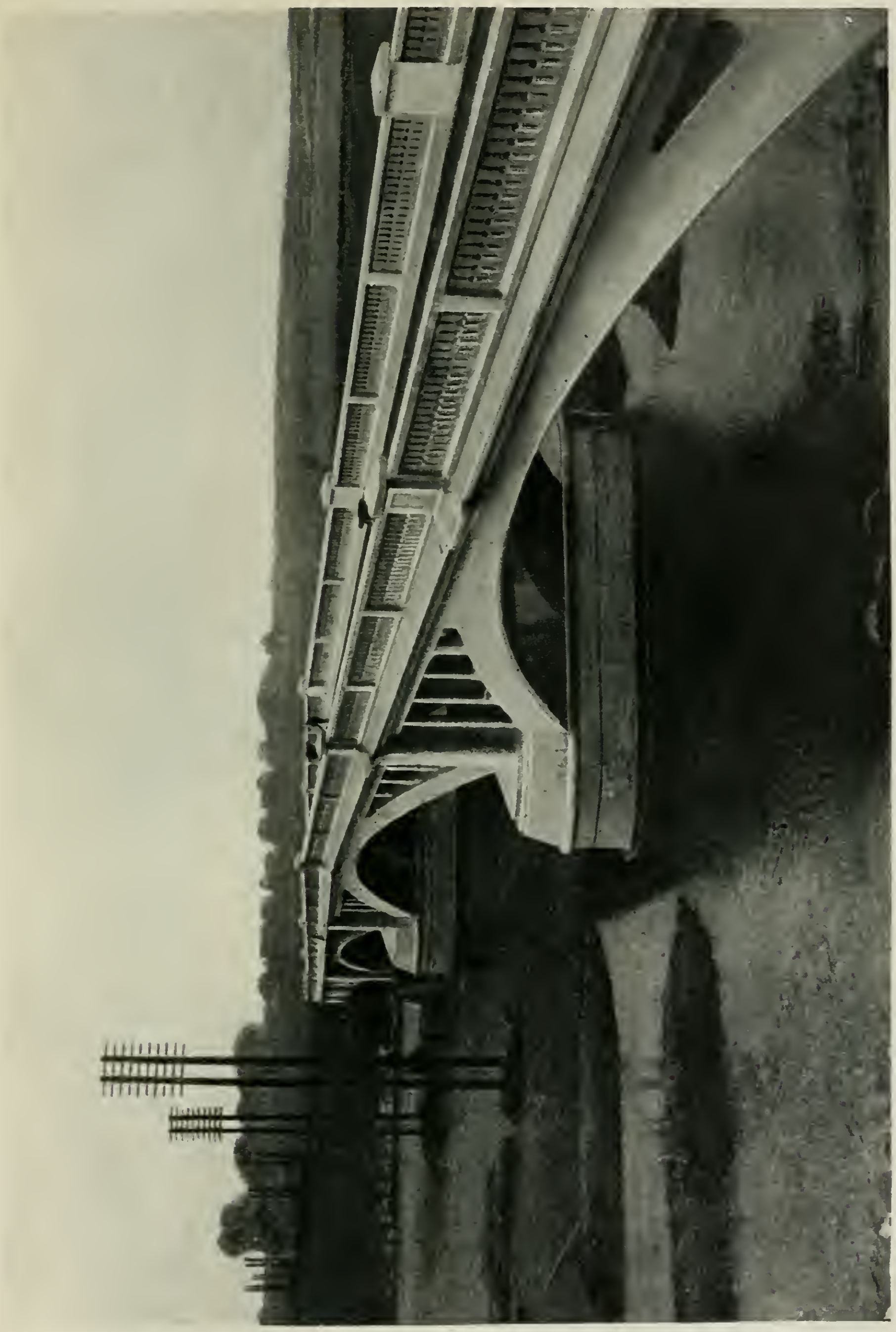


Part Elevation.

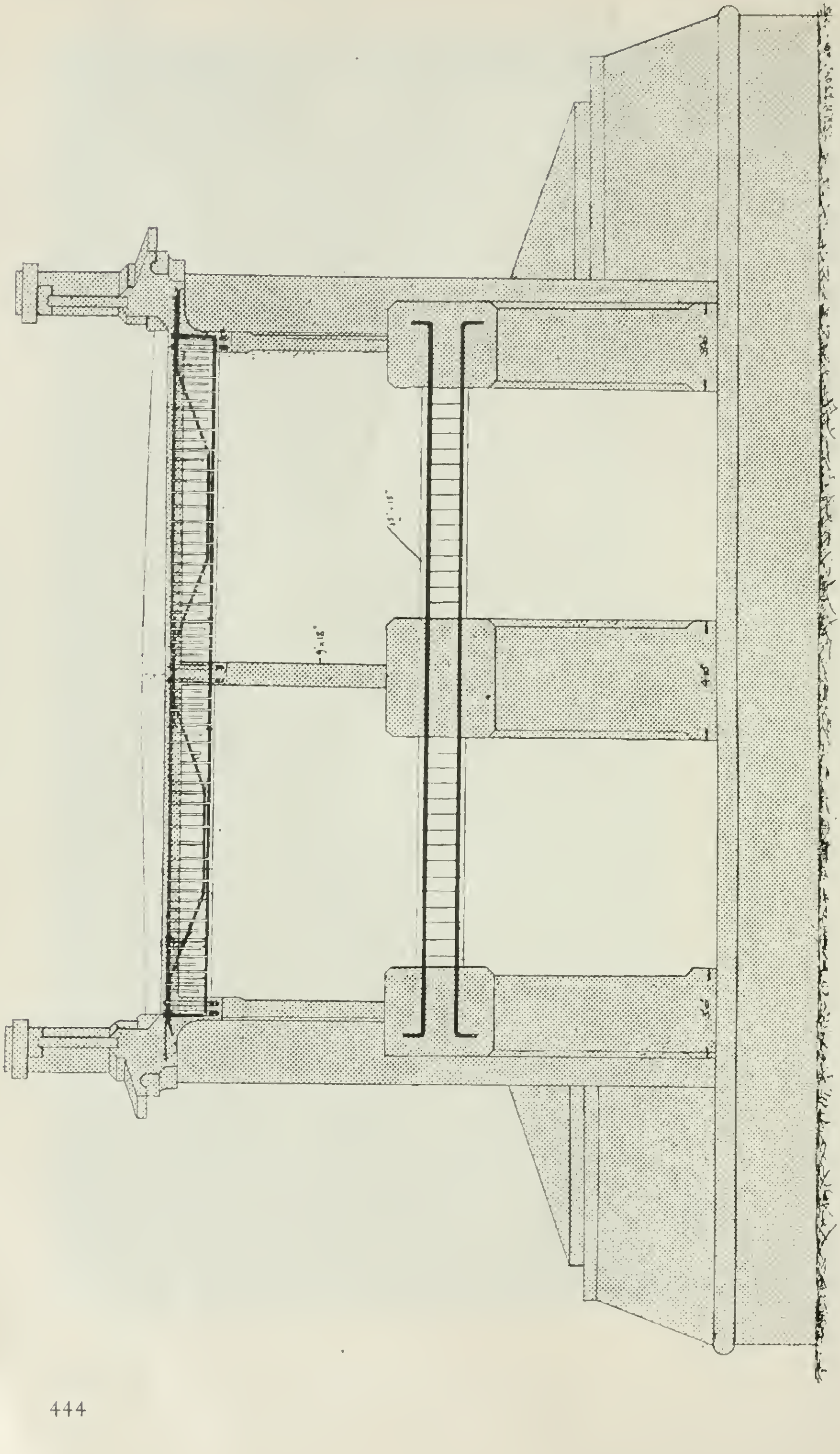


Plan.

The New Esk Bridge, Cumberland.



View of Finished Bridge.
THE NEW ESK BRIDGE, CUMBERLAND.



Cross Section.
The New Esk Bridge, Cumberland.

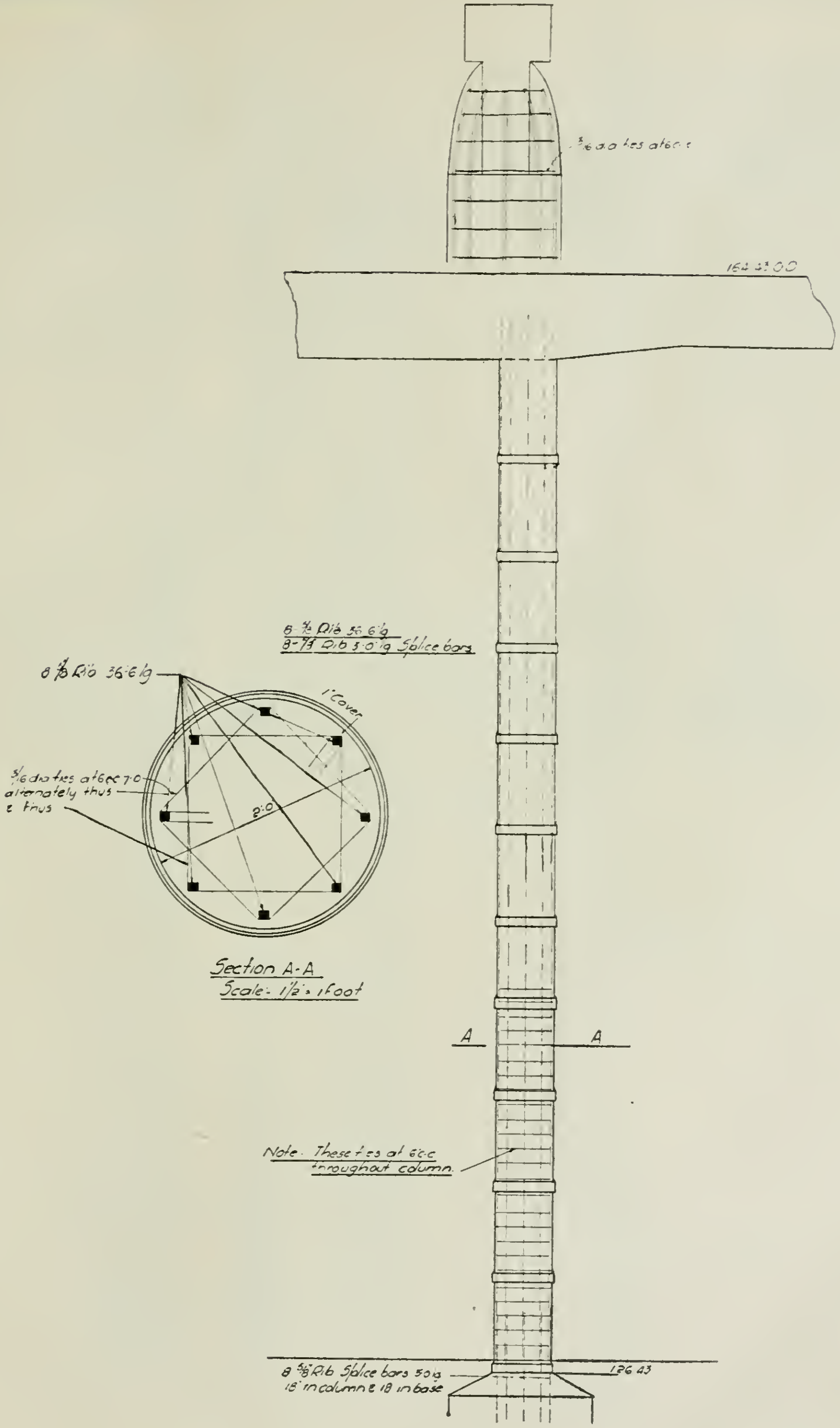


Fig. 1. Detail of a Column.

A Large Coal Store Viaduct for the Sheffield United Gas Co.

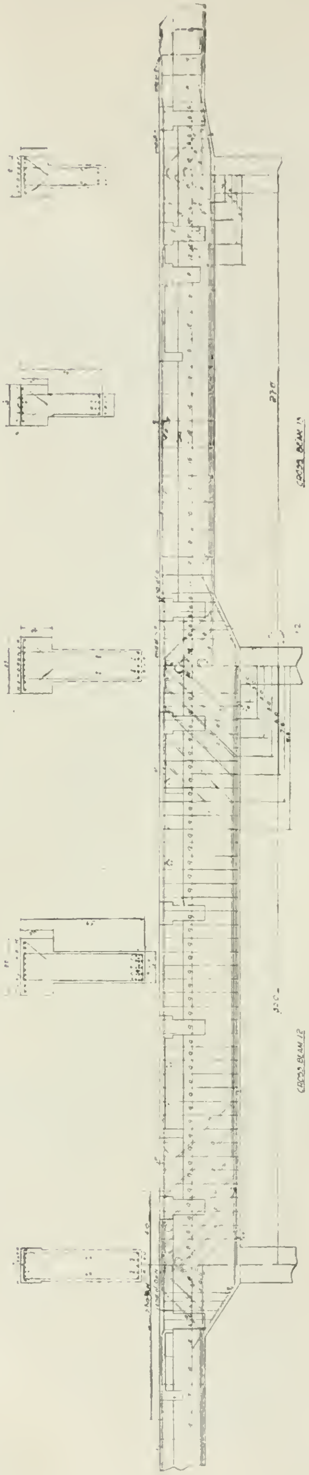


Fig. 2. Typical Detail of a Main Beam.

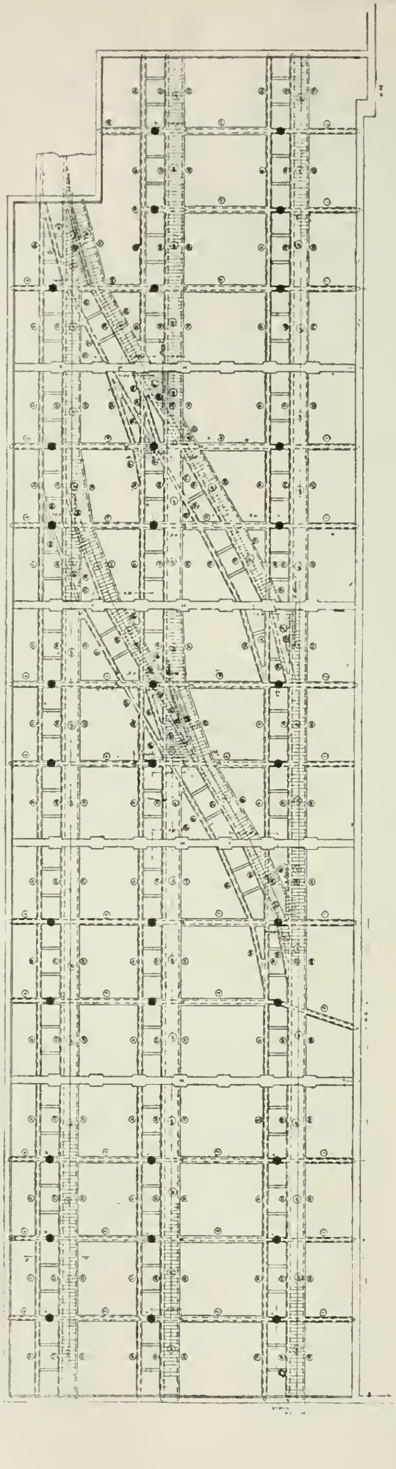


Fig. 3. Plan of Viaduct over Coal Store.

A Large Coal Store Viaduct for the Sheffield United Gas Co.

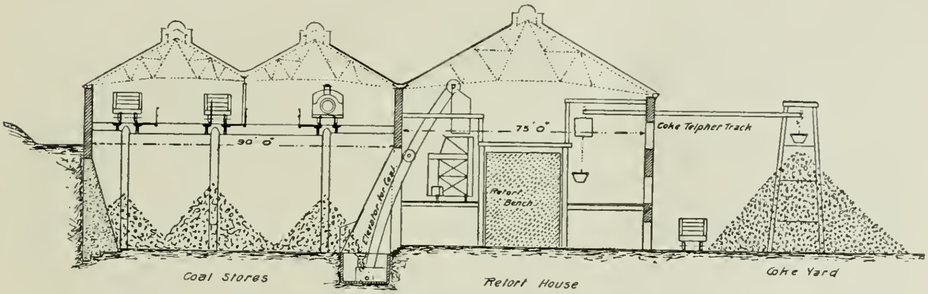
A LARGE COAL STORE VIADUCT.

This viaduct has been erected at the Grimesthorpe Station of the Sheffield United Gas Company. It is designed to carry trains consisting of 20-ton engines and 20-ton coal wagons, and has a capacity of 16,500 tons; and as the viaduct is 34 ft. above the ground careful designing was necessary for the stanchions or columns supporting it.

Fig. 1 shows a detail of these by which it will be seen that they are formed with eight ⅝-in. bars, with ties at 6-in. centres for the whole height. *Fig.* 2 shows a typical detail of one of the main beams, and may be said to explain itself.

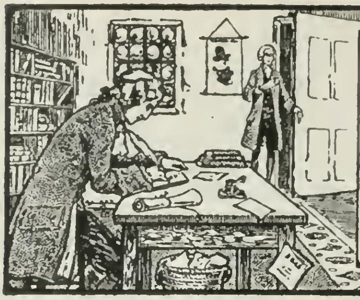
The viaduct is approached by a sloping way, and a general plan of it is seen in *Fig.* 3.

The work has been carried out to the designs of Mr. Jno. W. Morrison, M.I.C.E., Engineer to the Sheffield United Gas Company, the general contractors being Messrs. W. H. Treherne, Ltd., of Wellgate, Rotherham, and the engineers for the reinforced work were the Trussed Concrete Steel Company, of Caxton House, Westminster.



Sectional End Elevation.

A Large Coal Store for the Sheffield United Gas Co.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The New Sinkings at the Coventry Colliery, Keresley.—An excursion of members of the National Association of Colliery Managers (South Staffordshire, Warwickshire and Worcestershire Branch), for the purpose of inspecting the cementation process employed in connection with the new sinkings at the Coventry Colliery, Keresley, took place recently.

The Coventry Colliery may be said to have a three-fold interest, namely, economic, geological, and mechanical. The whole lay-out of the plant is on a large scale, and the sizes of the engine-house and engines were matters of general and favourable comment by the visitors. One shaft has been sunk about 400 yards and the other 370.

The great and special feature of the sinking has been the use of the cementation process, which has enabled the company to deal most successfully with the abnormal outbreaks of water met with in the course of the work, and, as explained by Mr. Liddell, the manager, in his speech, the work has in every way justified itself, as it has greatly lessened the expenditure and reduced the obstacles to the progress of sinking the shafts.

The utilisation of the cementation process was decided upon in November, 1914, and under the supervision of M. Albert François work commenced in No. 1 shaft at the depth of 490 ft. The operations in the first place consisted of the construction of a ferro-concrete plug 20 ft. thick in the shaft-bottom, during the construction of which the existing feeders of water were pumped by means of sinking pumps. After successfully closing off these feeders by means of cementation with the aid of the abovementioned plug, treatment of the water-bearing ground below was proceeded with, the extensive fissures encountered were satisfactorily treated, and sinking was commenced in March, 1915. Since that date the shaft has proceeded steadily down to a depth of 1,100 ft., the cementation process having been employed the whole time in five successive lengths of treatment. The shaft has been entirely lined with reinforced concrete, by means of which any water remaining in the sinking after treatment has been successfully closed off and a perfectly dry shaft obtained. The minimum thickness of reinforced concrete walling which has been employed is 18 in., and the pressure of water closed off corresponds approximately to the static head from the surface.

In No. 2 shaft similar work has been carried out to that in No. 1 shaft, the existing large feeders being in the first place closed off successfully by means of a ferro-concrete plug and subsequently sealed by means of cementation, after which the treatment of the ground was proceeded with and sinking was commenced at the end of April, 1915, at a depth of 558 ft. The work in this shaft has also proceeded satisfactorily with the aid of cementation down to the present depth of 1,200 ft., there having been in this case four concurrent stages of cementation treatment of the strata. This shaft is also completely lined with reinforced concrete from the point of commencement of the cementation process down to the bottom, and is quite dry.

In the early stages of cementation in both pits the period for completing the treatment of the ground was somewhat extended as a result of the large quantities of cement which were required in order to efficiently close off the fissures and breaks in the ground; such fissures, it being assumed, having been enlarged and cleaned out during the course of the previous period of pumping when the pits were being sunk with the aid of sinking pumps and cast-iron tubbing. The time taken, however, in the later stages of cementation has been quite normal, so that an overall speed of sinking—comprising treatment, sinking, and lining—of about 20 yards per month has been obtainable. Each of the two shafts is 21 ft. 6 in. diameter inside the walling.

With regard to the process of cementation its success has been a great relief to the directors. It had demonstrated its superiority over the old system of pumping in dealing with an excess of water. They were sinking the pits at a much less cost and with considerably less anxiety than under the pumping system.

Concrete for Mine Ventilation Stoppings.—In Bulletin No. 99 of the U.S.A. Bureau of Mines an account is given of a number of investigations carried out with various types of stoppings. Mine stoppings were considered. They included various kinds of board stoppings, brick stoppings, concrete monolith 8-in. wall, concrete blocks, slate or gob dry wall, and slate or gob faced with cement. The concrete stoppings were found efficient, and we give below the extract from the Bulletin under this heading as regards costs of erection and maintenance :—

" In many mines concrete is the most suitable material for use in the construction of efficient stoppings in the cross-cuts between main air passageways. Concrete stoppings may be constructed at reasonable first cost. They have low maintenance charges, they are durable, incombustible, and unaffected by water, and they have a high bearing strength to assist in supporting the roof.

" The installation costs as reported by several operators average : Cost of blocks, 4.74 dols. ; cost of cement mortar, 0.40 dol. ; cost of delivery into mine, 0.71 dol. ; cost of building stopping, 4.38 dols. ; total first cost, 10.29 dols. At many mines, where care has been used in the construction of the joint at the roof and the ribs, there have been no maintenance charges. At one mine it was reported that this item amounted to 5 cents per annum per stopping, based on an expenditure of 50 cents per year for every 10 stoppings.

" Renewal repairs are unnecessary in concrete stoppings, because, under ordinary mining conditions, the life of a concrete stopping is longer than the period during which service is required.

" There is little information available on the annual cost of emergency repairs for concrete stoppings. One operator reports that 10 per cent. of such stoppings are each year affected by heavy shots and require repairs amounting to 50 cents each. Most operators find no occasion for emergency repairs. A near-by windy or blown-out shot, or a general mine explosion, is usually the only extraordinary agent that destroys such stoppings ; and even then the wreckage from them is small and is easily cleaned up, and most of the blocks are suitable for re-use. When the bottom is soft and has a tendency to heave, it has been found advisable to lay the foundation course of cement blocks at a right angle to the other blocks, in order that a larger bearing surface may be obtained."

How to Make Concrete Resist Action of Sea Water.—Conclusions reached after an exhaustive search of the available technical literature on the subject of the destructive action of sea water on concrete, and a scientific analysis of a particular case by experimental study to determine the effect of various elements in the problem, are given in a report by W. Watters Pagon submitted to J. E. Greiner, consulting engineer, Baltimore, in the *Journal* of the Engineers' Club of Baltimore. These conclusions are summarised in the statements :—Use materials that cannot be attacked by the sea-water salts. Mix these so as to obtain the maximum density. Have no stones near the surface of the concrete, but use a mortar face 3 in. thick.

A more complete summary of the conclusions of this study of the requirements for making concrete that will have the greatest resistive power against the action of sea water (and also probably of alkali waters) is given in the following paragraphs :—

Requirements for Resisting Sea Water.—1. The addition of puzzolan in some form is widely practised in Europe, and appears to be theoretically correct. It has not been tried in America, to the author's knowledge, but is worth an exhaustive test. The amount should not be over one part for each part of cement, nor less than one-half part.

2. Waterproofing with substances that combine chemically with the free lime ought to be successful, and is well worth testing.

3. Between extreme high and low tides the concrete surfaces should be faced con-

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tinuously, without joints, with about 3 in. of 1 : 1½ or 1 : 2 mortar, made with sand as specified below, well cured before coming in contact with the sea water. The facing must be placed simultaneously with the backing.

4. The cement should be low in lime and alumina and contain as little gypsum as possible.

Requirements for Sand.—5. Sand must be silicious, uniformly graded from fine to coarse, with not less than 50 per cent. nor more than 70 per cent. passing through a No. 20 sieve, and not more than 3 per cent. passing a No. 100 sieve, and must have no organic matter coating the grains. It must be free from roots and easily disintegrated grains, such as feldspar, shells, limestone, mica, etc. It should be washed free from clay, and should show a tensile strength for 1 : 3 specimens not less than 85, 90, 95 and 100 per cent. of the strength of standard Ottawa sand of the same consistency, using the brand of cement that is to be used on the work, at ages of 1, 3, 7 and 28 days respectively.

6. Where concrete must be exposed to sea water without mortar facing, gravel should not be used. Broken stone should be hard, durable, trap, granite or other dense, hard, insoluble stone. It should not exceed ¾ in. in size, and should be free from crusher dust, sand, dirt, organic matter or other foreign substances. The mixture should be 1 : 1½ : 3 or 1 : 2 : 4, or should be proportioned for maximum density.

Fresh Water Should be Used.—7. Pure, fresh water should be used in sufficient quantity to permit the materials to be well puddled and spaded, so that no later surface treatment or patching will be required, but not sufficiently to materially retard the setting of the cement. Care must be exercised, however, to prevent the formation of laitance or pockets of neat cement or very rich mortar.

8. Forms should be tight to prevent leakage of cement, or, where concrete must be submerged immediately, to prevent contact with sea water.

9. Facing should be reinforced with steel, well covered with mortar and securely anchored to the backing.

10. No surface treatment should be given.

11. The work should be allowed to harden two weeks, if possible, before coming in contact with sea water. Two months is better.

Avoid Low Temperatures.—12. Sea water work should never be done in cold weather, with temperature below 40 deg. Fahr.

13. Where possible precast, mortar-faced blocks cured in damp sand for at least one month should be used. The facing should extend back at the joints to prevent saturation of the backing. The joints should be pointed with 1 : 1 mortar of coarse sand.

14. The most durable surface will be obtained if granite or other dense stone be used as facing. This should not be less than 6 in. thick, anchored back with wrought-iron clamps, and pointed with 1 : 1 mortar of coarse sand and cement as noted above.

15. On mortar or concrete surfaces the growth of barnacles, moss, etc., will frequently afford protection.

How to Store Cement.—In a short article in *Engineering News* Mr. S. P. Baird writes as follows :—

"It is sometimes thought that only one thing is necessary for the safe and effective storage of cement—a tight roof. Many years' experience has convinced the writer that water-tight storage is not enough, and he has formulated the following principles for cement storage :—

"1. Cement will retain its strength for an indefinite period when stored in air-tight containers.

"2. Cement will be injured less by storing in paper sacks than in cloth sacks, everything else being equal.

"3. Cement in any kind of commercial packages will be injured least while in storage if the packages are piled as closely together as possible. In other words, the outside surface of the pile of sacks should be the smallest amount possible.

"4. Piles of cement sacks should be covered with a tarpaulin to prevent as far as possible the circulation of air through the pile.

"Note the word 'tarpaulin'; an ordinary canvas cover is not a tarpaulin, but a paulin. Five parts coal tar, one part gasoline, and one part good japan drier make a water-tight black coating for canvas.

"Surface condensation often takes place on a stored sack of cement. The moisture is carried into the cement to its very great injury as well as the practical destruction of the sack. The destruction of the sack may not be evidenced at once; but it may be returned to the mill and refilled and sent to some other job, where it bursts and is paid for by a person who was in no way responsible for its condition.

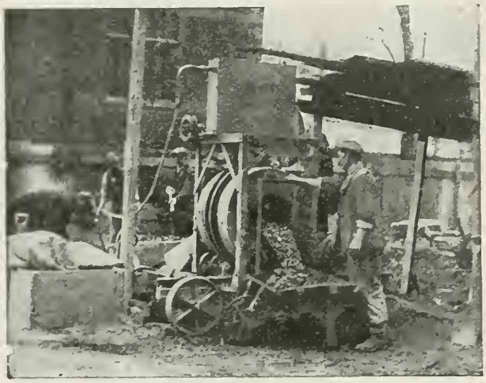
"There is a saying among cement men that if you turn your cement—that is, move it from one pile to another—once a month, it will not be injured by an indefinite period of storage. This is not the case; pile it closely and cover it as nearly air-tight as possible and you will have very little caked cement. If the cement is caked it is better to let it alone until you are ready to use it rather than break the cake, thus presenting fresh cement to the action of the air."

Patching Concrete Pavements.—The patches in concrete pavements at Gary, Ind., are allowed to set for 48 hours after placing. A tar covering, at the rate of half a gallon to the yard, is then put on the patch and traffic turned on at once. Experience has shown that the method is satisfactory. The tar wears off in six or seven months, and the concrete patches are thoroughly hardened.

Reinforced Concrete in the Cameroons.—Under an Order issued by the General Officer Commanding the Expeditionary Force expanded metal, in the shape of wire netting, etc., for reinforced concrete, will be admitted to the country free of import duty.

PUBLICATIONS RECEIVED.

We have received another booklet issued by the British Reinforced Concrete Engineering Co., of 1, Dickinson Street, Manchester. The publication in this instance deals with the reinforcement of floor slabs and ground floors with B. R. C. Fabric. Some useful tables are given showing the size of fabric to be used for various classes of floors over various spans. The tables are for floors continuous over a number of spans, and include roofs, offices and dwellings, warehouses, schools, shops and public buildings, ball-rooms and drill halls. By the aid of these tables the architect or builder can at once determine the size of the fabric needed. Illustrations of the different types of spans are given.



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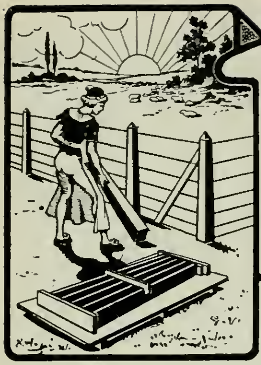
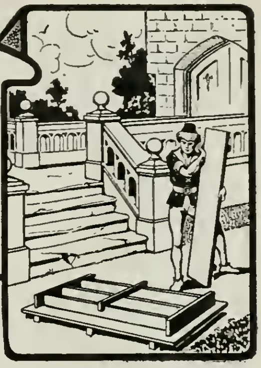


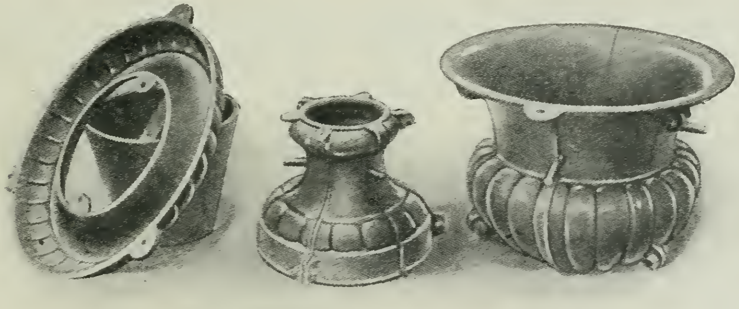
CONCRETE THE MONEY SAVER



ORNAMENTAL CONCRETE PRODUCTS.

INTRODUCTION.

Experience has shown that concrete can be employed to great advantage for decorative purposes on the exterior of houses, and also in setting off a garden to the best advantage, and with as little expense as is consistent with good workmanship. In fact, concrete can be used in the form of ornamental columns for verandahs, porches, for balustrades, garden seats, lawn vases, etc., etc., and at a much lower cost as compared with stone or terra-cotta. It is rather remarkable that in this country concrete has not been employed to a far greater extent in our parks, recreation grounds, public and private gardens, as with care it can be adapted to practically any requirements.



(a) *(b)*

Fig. 1. Iron Mould for Vases.

We propose here to give a few notes and hints on how to deal with concrete in an ornamental form, so that any builder or gardener may make articles for the purpose of ornamentation of the garden, etc. It would be well if those controlling the arts and crafts schools of this country would give some attention to these ornamental uses to which concrete can be applied, with far greater ease than terra-cotta, and without the difficulties as to shrinkage that are met with in the latter material. It should also be remembered that with concrete all articles made in the one mould are exactly alike, while with terra-cotta discrepancies are practically always visible.

Another point which must not be lost sight of is that concrete, if properly made and to a good surface and colouring, is more artistic in the garden than red terra-cotta. One of the great advantages of concrete garden ornaments is that they can easily be made on the spot, and thereby the risk and cost of freightage is saved.

MOULDS.

Moulds for the articles mentioned in this supplement can be made in iron, wood, or plaster, according to the quantity required to be made with the mould. This, of course, depends upon the locality to a large extent, but for vases, etc., iron moulds can now be purchased very cheaply, and it will be found that the better the mould the better the product.

Fig. 1 shows parts of an iron mould which when assembled will form a vase as shown in *Fig.* 2. In some instances the parts marked *A* and *B* are made separately, with a small hole cast in the centre of each, so as to allow a bolt to pass through, and hold them together. When this is the case, it is always well to run some liquid grout around the bolt before tightening it up, and, after the grouting has set, then tighten it up to the necessary requirements.

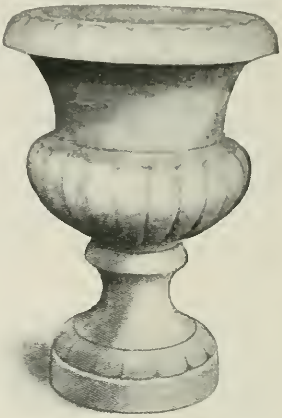


FIG. 2.

Figs. 3 and 4 show some vases of different patterns which can be made on the moulded principle. With care in the use of same quite a number of articles can be produced from one mould. The surface should be treated with shellac when the plaster has hardened and is quite dry. Moulds for the manufacture of copings, balusters, etc., can be made of yellow pine, American white wood, or bass wood. After use the mould should be oiled, in order to preserve it. Care should also be observed in the use of the rammer. The top edges, where the material is filled in from, should be ironed up by means of strips of iron about 1 in. by $\frac{1}{8}$ in., so as to protect the sharp wooden edges from the rammer.

Fig. 5 shows a wooden mould for balusters which is quite simple in construction. The surface of this mould should be treated with a coating of shellac dissolved in methylated spirit. *Fig.* 6 shows an iron mould ready for use, while *Fig.* 7 illustrates how the mould can be taken away. *Fig.* 8 shows the finished article, which is a hitching post, and for appearance and stability wood cannot be compared to it; at the same time it can be made at less than half the cost of a wooden post.

A plaster piece mould can easily be made off an existing stone vase, but care must be taken to see that none of its ornaments are undercut; if so, the plaster cast or mould will not leave the stone vase. This also applies when an article is being made in a mould. If a portion of the mould is undercut the article will not leave the mould clean, and that particular portion will pull away. When a plaster mould is to be made off an existing stone or terra-cotta article, the only things needed are two bottomless boxes which are deep and wide enough to allow of a sufficient thickness of plaster on each side, top and bottom of the article. If the article (as an example) for which the mould is to be made is a round pillar with square cap and base, the exact half of the pillar must be found, and it must then be set in moulders' sand or modellers' clay up to the half, and the other half must be left exposed. (See *Fig.* 5a.) Upon this the top half of the box is placed, and the joint between them is made tight, so that when the plaster is poured in it cannot escape. The joint of the mould—*i.e.*,

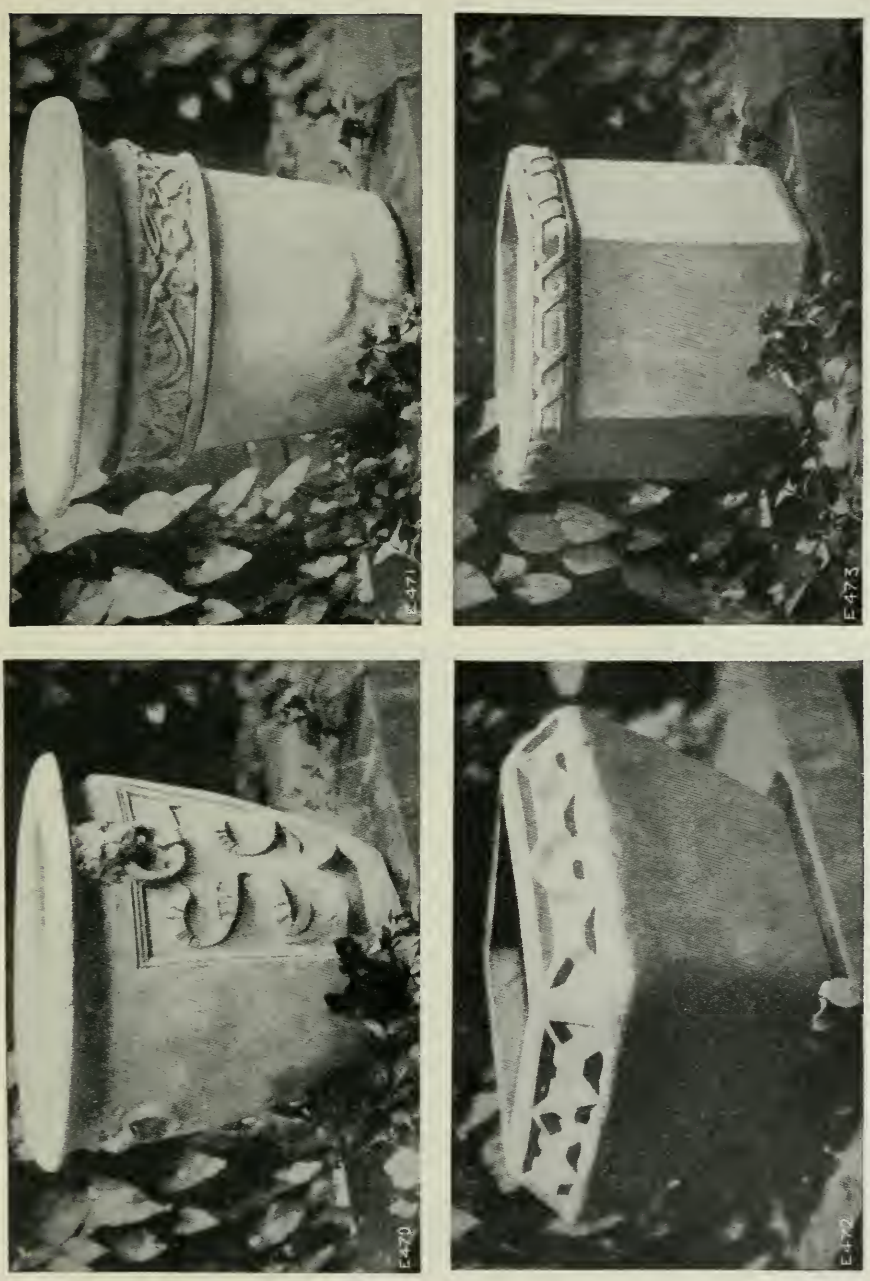


Fig. 3. Some Concrete Vases.

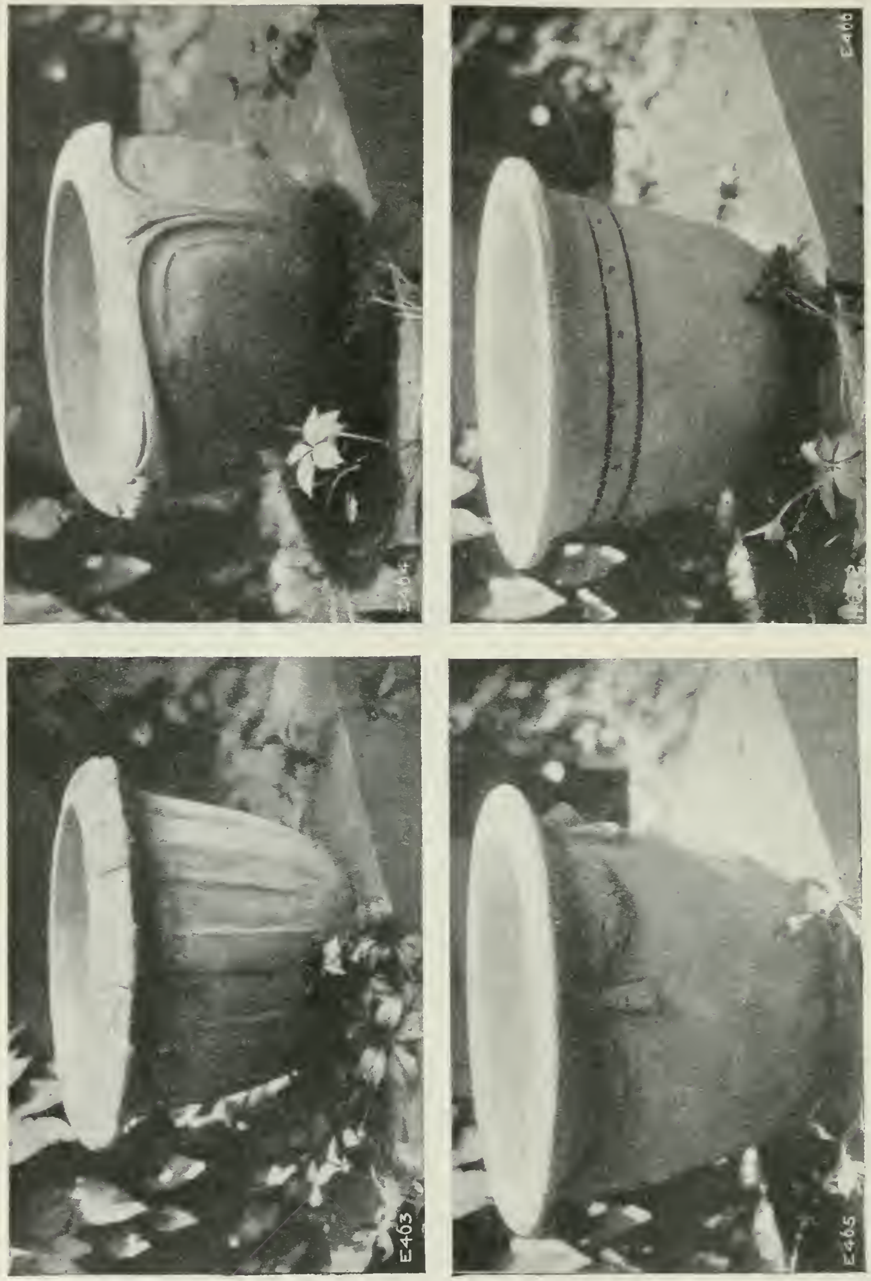


Fig. 4. Some Concrete Vases.

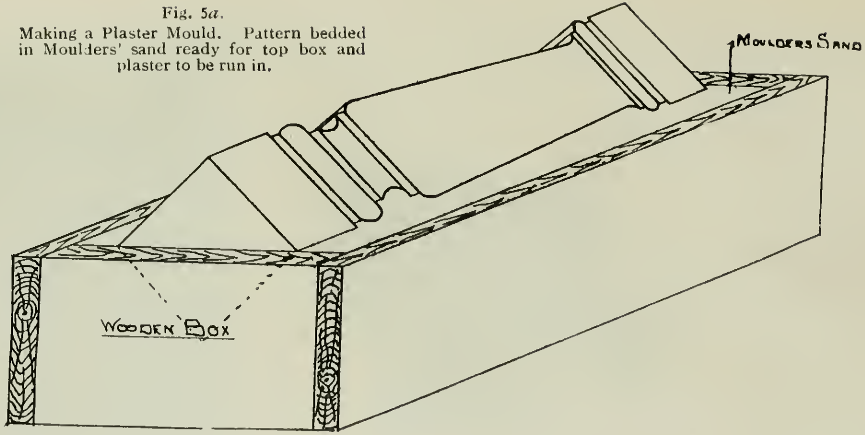


Fig. 5*a*.
Making a Plaster Mould. Pattern bedded in Moulders' sand ready for top box and plaster to be run in.

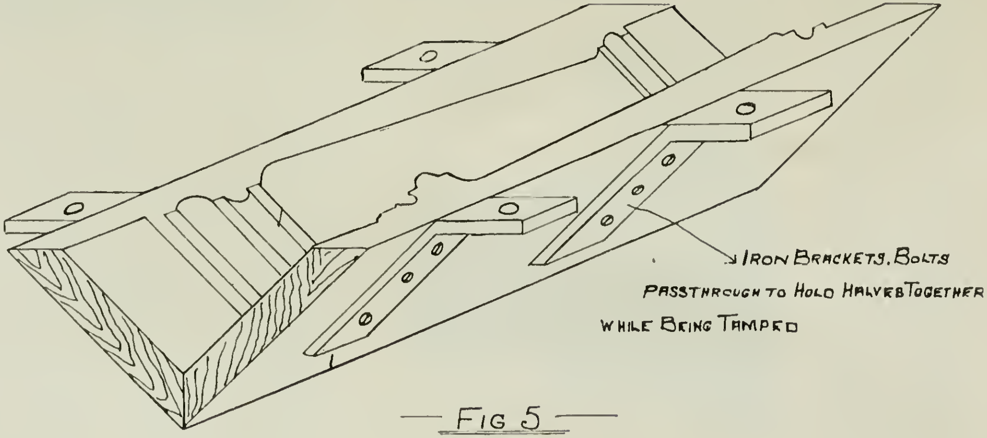
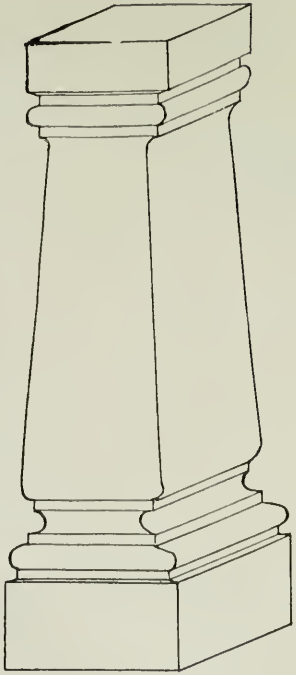

Iron Brackets. Bolts pass through to hold halves together while being tamped

FIG 5

HALF MOULD MADE IN WOOD FOR BALUSTER. TWO HALVES TO COMPLETE MOULD



A SIMPLE BALUSTER

where the sand is—should be perfectly straight and smooth. When all is ready, mix plaster, and pour into top box. When the plaster has set, turn the two boxes over and remove the half which has the sand or modellers' clay in it. Also remove all the sand or clay from around the pillar, leaving half of the pillar exposed from the plaster. Clean off the joint or face of the plaster, and oil same. Next put on the other half of the box and repeat the operation of pouring in the plaster. When this is completed and the plaster hardened, part the mould (as it is now) at the joint, and care must be taken to lift it up square and parallel, so as not to disturb or break away the sharp edges of the plaster around the pillar. When this is done, one-half of the mould is visible, and the pillar can then be removed carefully from the other half, and the mould is then complete. After having been left to harden off for two or three days, a coat of shellac or French polish can be applied. This will protect the plaster from the water in the concrete, and also keep it from sticking to the mould.

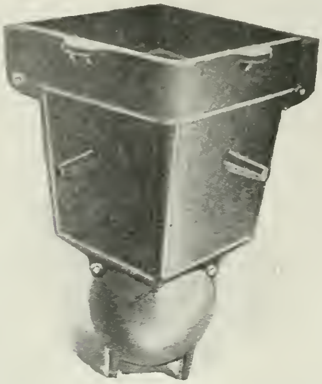


FIG. 6.

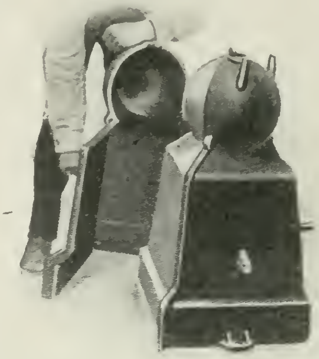


FIG. 7.

MAKING ORNAMENTAL CONCRETE ARTICLES.

The mixing and grading of materials is much the same as was described in the supplements on "Concrete Fencing Posts," and only a few additional remarks are, therefore, required here. The mixture for the articles described here is stronger than that for fencing posts, being chiefly composed of 2½ of aggregate to 1 of cement.

Aggregates suitable for this class of work are coarse sharp sand and crushed marble in different colours. The material may be run into the moulds in the same way as when making fence posts, and left to harden off before the mould is removed. Another method is to wet the material just sufficiently, so that it will ram without the water appearing on the face of the article. This will allow the mould to be removed from the article at once instead of being left until it has hardened off. This also allows the mould to be in use continually, which means that perhaps it is possible to make ten articles in one day. But if the article is made on the wet principle it will take three days before the mould can be removed. This shows that for rapid production the "semi-dry" principle is the best.

Articles of different colour can be made by the addition of colour to the cement. It should be noted that the colour should be well mixed with the cement before adding the aggregate to the cement.

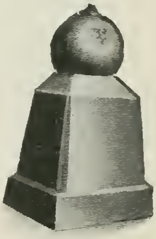


FIG. 8.

This ensures perfect mixing of the cement and colour, but if the aggregate, cement, and colour are mixed all together when the water is added it will be found that the colour is patchy, which shows that if all three are mixed together it is practically impossible to mix *perfectly*.

Another method of making vases, boxes, etc., in concrete is to make wire forms, as illustrated in *Fig.* 9. By this method the ingredients, consisting of cement, sand, marble, or granite dust, are well mixed and wetted down with water, and then turned over and trowelled until the mixture is a plastic mass. As is well known, it is impossible to form this plastic material unless it is placed in a mould, or unless a form is used to hold it in shape while it is in its plastic state.

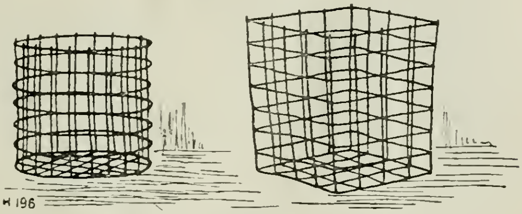


Fig. 9. Wire Forms for Making Concrete Vases, Etc.

The first step after making the wire forms is to build the concrete gradually up in them. It is claimed that with the use of wire forms, as illustrated, it is simpler when there are but one or two of the same shaped articles to be made. When a number is required it is better to make either a wooden or plaster mould (as before described), as these can be used over and over again, while a fresh wire form has to be made each time.

POLYCHROME CONCRETE.

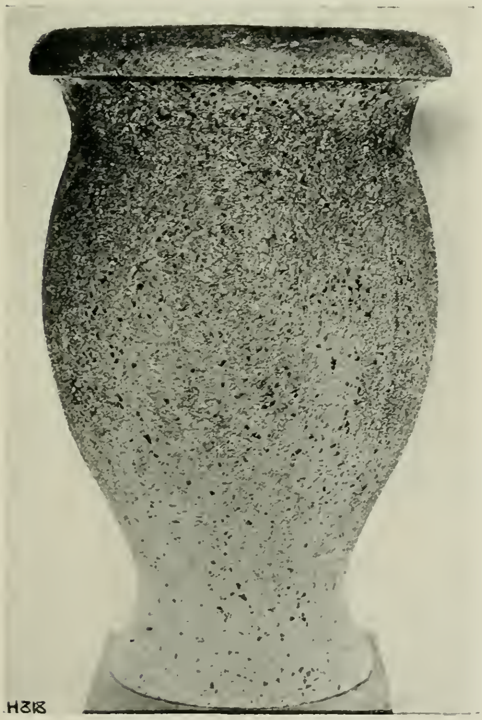
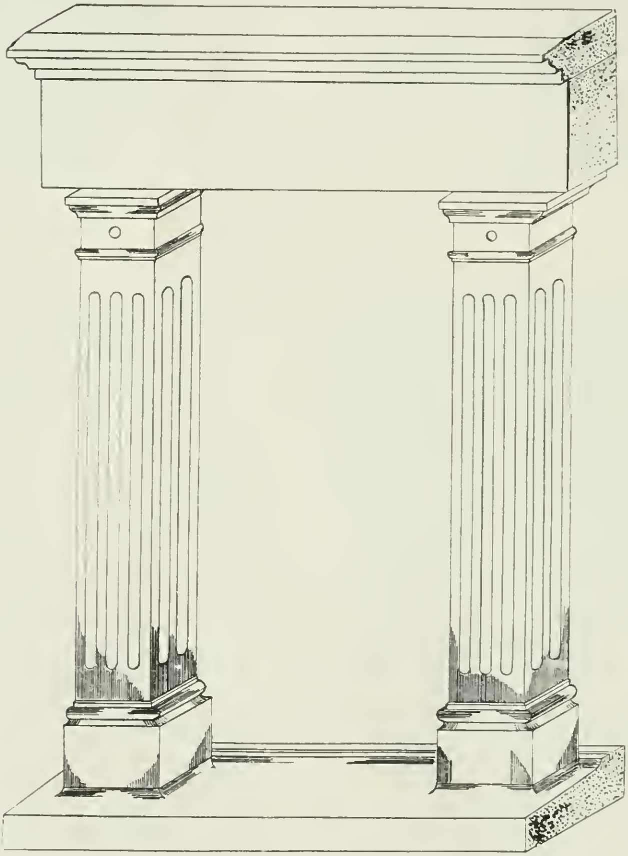


Fig. 10. Polychrome Concrete Vase.

This is a material which hardens into permanent stone, the component parts of which may be pre-selected and modelled into shape to meet the requirements of the user and also to the fancy of the designer, having the distinct advantages of obtaining both colour and texture at a cost far below that of cut stone. *Fig.* 10 shows a polychrome concrete vase, which was made with "Vulcanite" Portland cement (a U.S.A. brand of cement), crushed black and yellow marble screenings, all of which pass a $\frac{1}{8}$-in. mesh sieve, and black and yellow marble chippings, which will pass a $\frac{1}{2}$-in. sieve and can be retained on a $\frac{1}{4}$-in. sieve. The aggregates for this vase were mixed fairly wet, and were moulded in a plaster mould. As soon as the concrete was hard enough to retain its shape, which took about forty-eight hours, the inside core was removed. Inspection would then show whether the vase would be hard enough to allow the outside mould to be removed. If so, remove the outside mould, and the surface should be immediately scrubbed with a stiff (house) scrubbing brush and water. The concrete should be brushed until the larger aggregates all appear, and in order to obtain texture the brushing should be continued until they are thrown slightly in relief. The vase is then cleaned off with water and kept damp for about two weeks, after which it is washed off with a solution of dilute muriatic acid. The acid is left on for a couple of minutes and then scrubbed off with clean water and scrubbing brush. The effect as to colour, texture, and form is permanent. The bonding material (Portland cement) is removed from each particle of stone, there being no artistic, practical, or technical reason why the bonding material should be displayed to the eye. This opens up a wide field for garden ornaments, decorative panels, and balustrades, etc. The method and effect undoubtedly comply with all fundamental principles of art.

(To be concluded.)



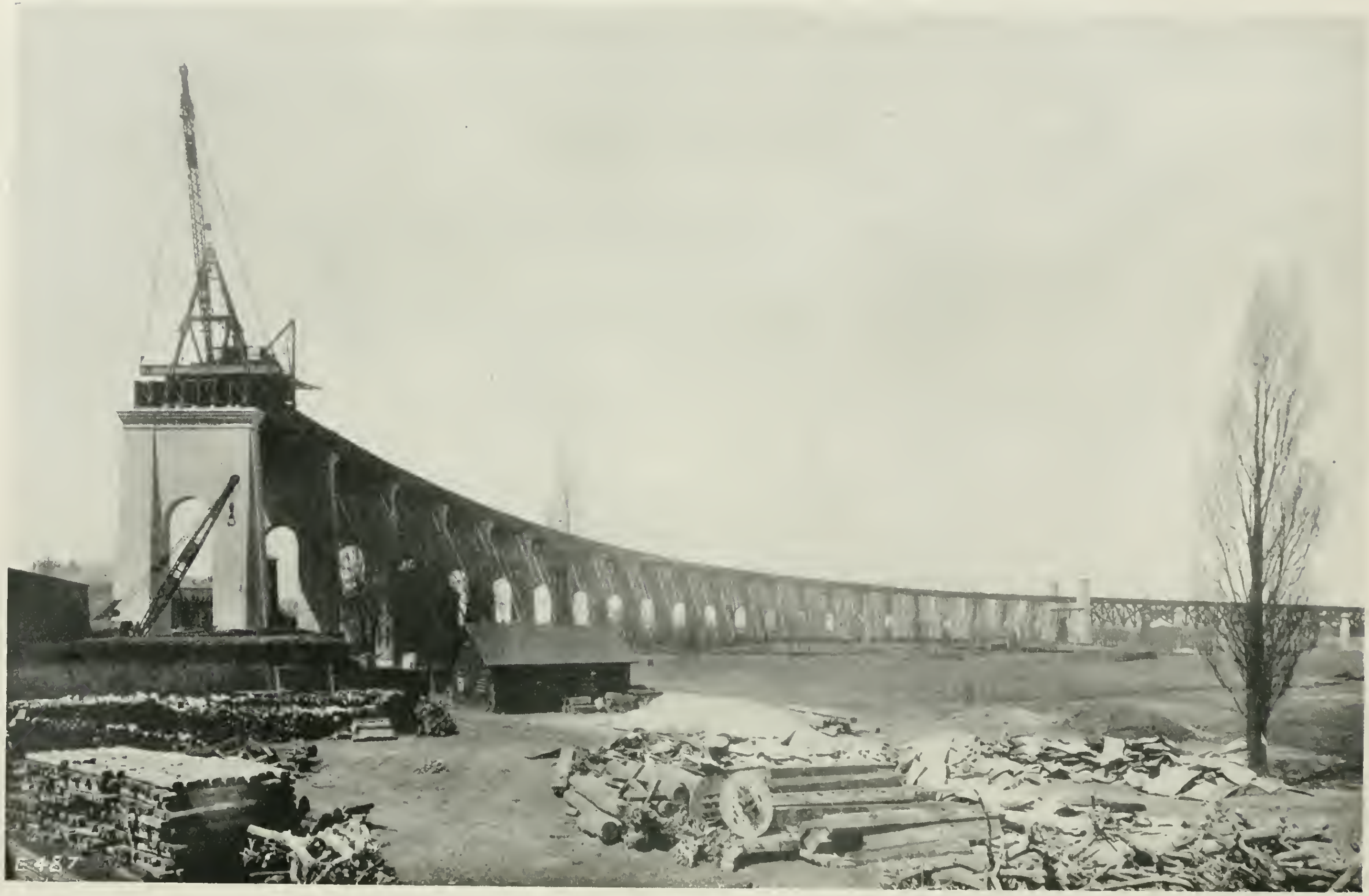
View of Mullions, Head and Cill for Window made of Concrete.

(Note.—These mullions are fluted on both sides, so as to avoid making them specially for each hand.)

The following subjects have been dealt with in previous supplements:—

Concrete Fence Posts.

The Adaptability of Local Materials. Concrete for Farm Work.



Ward's Island Viaduct.
HELL GATE BRIDGE, U.S.A
(*See page 499.*)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XI., No. 9. LONDON, SEPTEMBER, 1916.

EDITORIAL NOTES.

CHEAP COTTAGE CONSTRUCTION.

THERE has been a great deal of discussion in the Press recently on the question of economical cottage construction, and many writers have pointed out the urgent necessity of providing more houses in rural districts. Under "Memoranda" in this issue we publish an extract from an article which appeared in *Municipal Engineering and the Sanitary Record,* and the subject is of such widespread importance that all our readers will read the extract with interest.

There is no doubt that there is a great need for progressive movement with regard to rural housing, and at the present time a great difficulty exists in being able to design and construct even the smallest cottages at anything like a reasonable cost where convenience, sound work, and a reasonable finish are provided, and every effort should be concentrated towards a solution which will enable the initial cost of erection to be reduced.

In the article published in this issue and referred to above the question of concrete as the most suitable material for cheap work is discussed, and we have repeatedly drawn attention to the great possibilities of this material. We cannot agree with the statement that the life of a concrete cottage has a maximum of thirty years as against sixty years for brick. It is a well-known fact that the strength of concrete increases with its age, and the concrete cottage will undoubtedly last much longer than that constructed of brick, as the latter invariably begins to decompose under the action of the weather after a period of years, and thus the strength decreases with age. It would cause the author of the article some considerable trouble to state any instance where a concrete structure had not been able to withstand the effects of weather conditions for considerably over thirty years. As regards the comparative costs of brick and concrete, in every case that has been brought to our notice concrete has proved to be the cheaper material of the two, and there is no doubt that, generally speaking, economy will be effected by the use of concrete. No definite comparison can be made, however, without due regard to the circumstances in each particular case, as so much depends upon the local conditions.

When sufficient and suitable aggregate is readily obtainable in the vicinity of the site the saving effected with concrete will always prove considerable, while even under adverse conditions it will invariably be found that some saving is effected. There is no doubt that concrete is becoming more universal in cottage work, and those responsible for housing schemes are beginning to realise that the material has great possibilities. This is a decided step forward towards the ultimate realisation of cheaper cottage construction, as the enquiries and investigations that are made will result in the material becoming more popular, and its more extensive application will remove prejudice and evolve standard methods. Apart from the initial cost of the materials, it must be remembered that the building of brickwork requires the services of tradesmen whose rate of wages is higher than that of the labourers who can be employed, under proper supervision, for the building of concrete structures. This is highly important in rural districts where local labour can be used, as the importation of a large amount of labour is always a source of expense to the contractor and a consequent increase in the price of building. There are, of course, many other factors to consider in cottage work which materially affect the cost, such as the planning, fitting up and general finishing, and if these are not properly dealt with the evolution of the cheap cottage will never be attained; but the main constructional material will always play an important part in the total cost of the work, and it deserves some attention at the outset.

Another point to consider is that the main constructional material will also affect the cost of the finishings, because with such a material as concrete for walls it should be possible to obtain a good face with the minimum of plaster, and good work has been executed where one coat alone has proved sufficient. For internal walls in sculleries and such places, where no plaster is required, a very good finish can be given with the use of concrete that will be superior to that obtained with brickwork.

The whole community is affected by the question of cheap building as applied to domestic work, and, although a lot of attention is directed towards the construction of large structures, it seems that little attention is given to cottage work, and it is here that an excellent field can be found for the energies of the various institutions connected with the building industry.

It must be remembered that the primary consideration in this class of work is that of the rental, which must of necessity be low, for the wages of the occupants are such that a few shillings per week may make all the difference between comparative comfort and a struggle for existence, and at the same time it is essential for the welfare of the workers that their homes be sound and dry and fitted up with the necessary conveniences of modern sanitation.

Domestic work is sometimes specialised in by architects and others, but more often it is looked upon as so very simple that no particular talent is required to deal with this class of work, whereas it presents many problems which are worthy of the best brains in the country, and not the least of these problems is that of evolving the cheap cottage which is comfortable and weatherproof. It is to be hoped that the possibilities of concrete will be thoroughly investigated, and in this way further progress will be made in a form of construction which has extensively developed under the conditions of war which call for rapidity and economy.

NEW SODALITY AND CONFRATERNITY BUILDING, CARMELITE PRIORY, AUNGIER STREET, DUBLIN.

The following particulars and illustrations of a concrete building erected in Dublin have been sent us by the Architect, Mr. Charles B. Powell, of Dublin, who was responsible for the design adopted. It is of interest to note that the building sustained but little damage during the recent riots, though practically situated in the centre of the scene of conflict.—ED.

THIS building, just completed, was commenced in June, 1914, but its progress was delayed at intervals owing to its having to be executed in sections, and on account of labour and material difficulties caused by the war.

All structural work throughout is of concrete, reinforced where necessary by steel rods, with a few steel girders in special positions where the bulk of reinforced concrete beams was undesirable.

The foundations and principal walls are of concrete, composed of six parts clean broken stone to pass a 2-in. ring, with sufficient clean sharp sand to fill all interstices, to one part standard London Portland cement.

All internal partitions, principally on upper floors, are of concrete, 4 in. thick, composed of five parts clean gasworks coke breeze to one part Portland cement, reinforced with $\frac{1}{2}$-in. diameter round rods, 4 ft. apart, vertically and horizontally, hooked and secured in walls, floors, etc., at ends.

Flues are lined with fireclay tubes, the grates being of low fire barless type.

The basement floor (stores) is of 6 in. thick concrete as for walls, finished with granolithic.

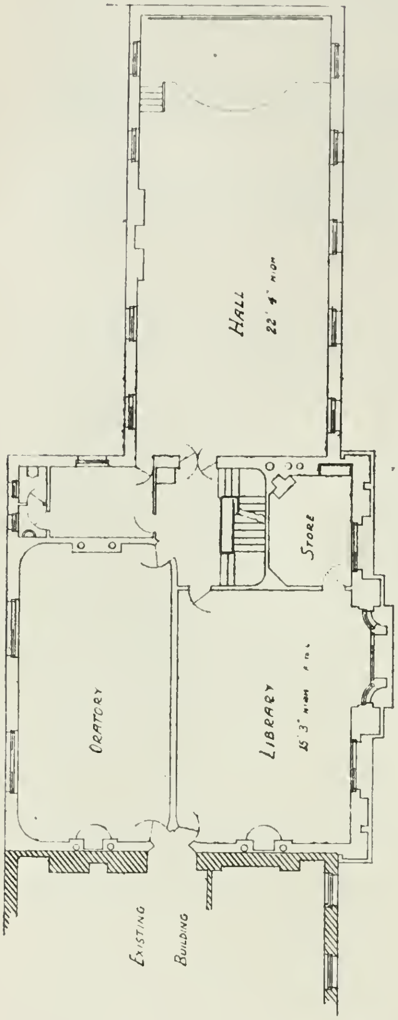
All other floors and roofs are formed of concrete, composed of three parts clean broken brick, to pass a $\frac{3}{4}$-in. diameter ring, two parts clean fine gasworks coke breeze, and one part Portland cement, all reinforced with expanded steel, with tension strips of suitable widths over lines of support.

The ground and first floors are 6 in. thick with No. 10 expanded steel, diamond mesh. The second floor is 8 in. thick, reinforced with No. 2 metal, rib mesh, and the third floor, centre block, is 7 in. thick, reinforced with the same material.

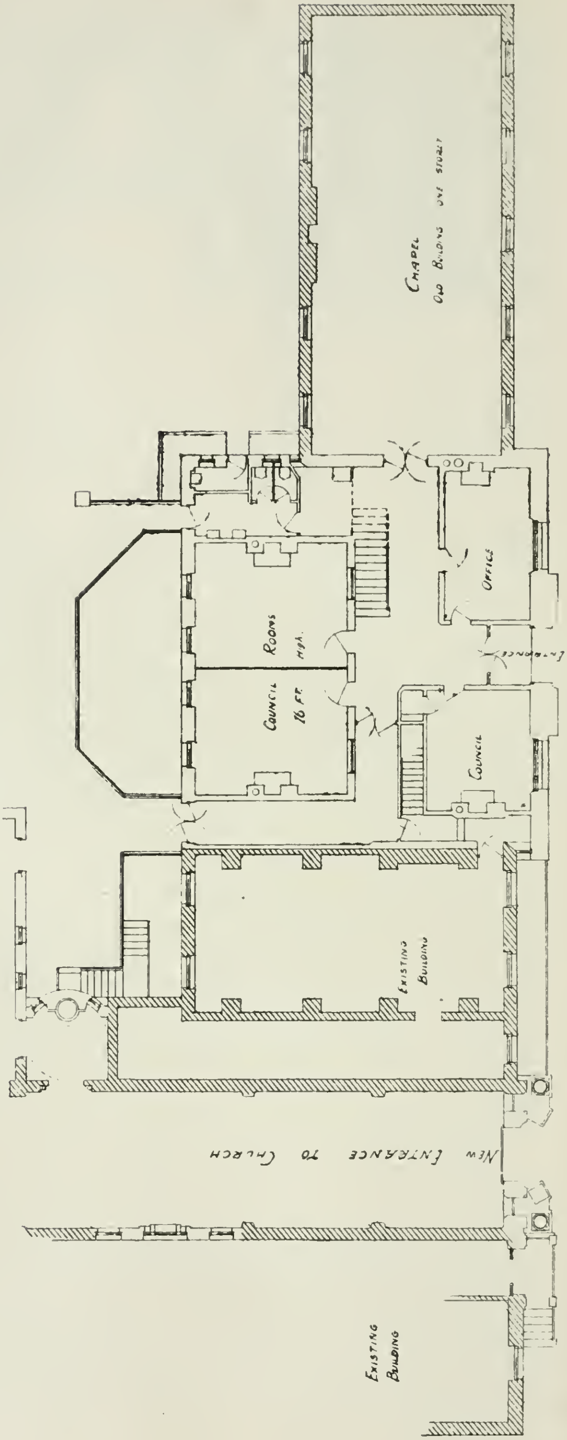
The third floor, over the hall, is 6 in. thick concrete with No. 10 metal, diamond mesh.

The roofs generally are similar to the third floor, the upper surface being finished with asphalte, with garden plots.

All the stairs are formed of concrete cast *in situ* with the walls and partitions, the concrete being made of four parts broken brick, to pass a $\frac{3}{4}$-in. diameter ring, with enough clean sand to fill all interstices, to one part Portland cement. The treads are grooved and formed with moulded nosings and risers in granolithic, and each flight and landing is reinforced with No. 10



First Floor Plan.



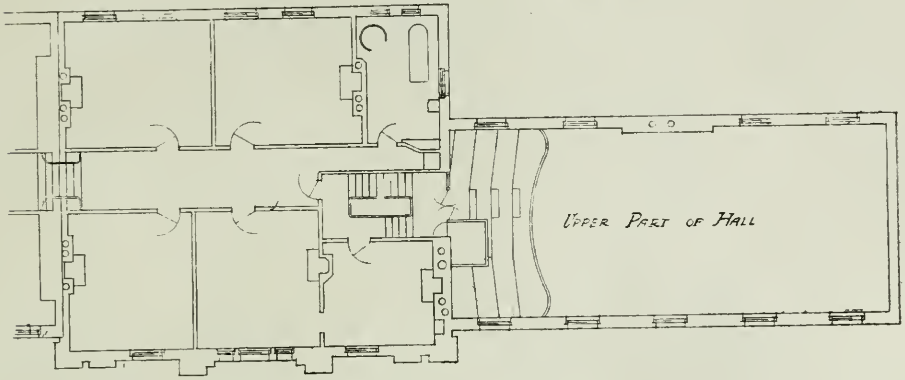
Ground Floor Plan.

New Sodality and Confraternity Building, Carmelite Priory, Dublin.

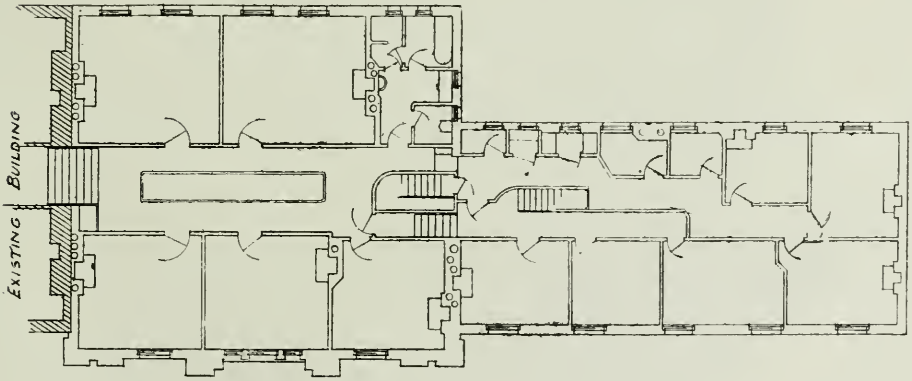
expanded metal. In two cases, however, as the metal was unobtainable, ½-in. diameter steel rods were substituted.

The stairs are finished with wrought iron ornamental balustradings.

The principal external cornice, 4 ft. in projection, is of cellular construction, the top, bottom, and dividing walls being reinforced with ½-in. diameter bars.



FIRST FLOOR PLAN 16' 0" HIGH F TO C



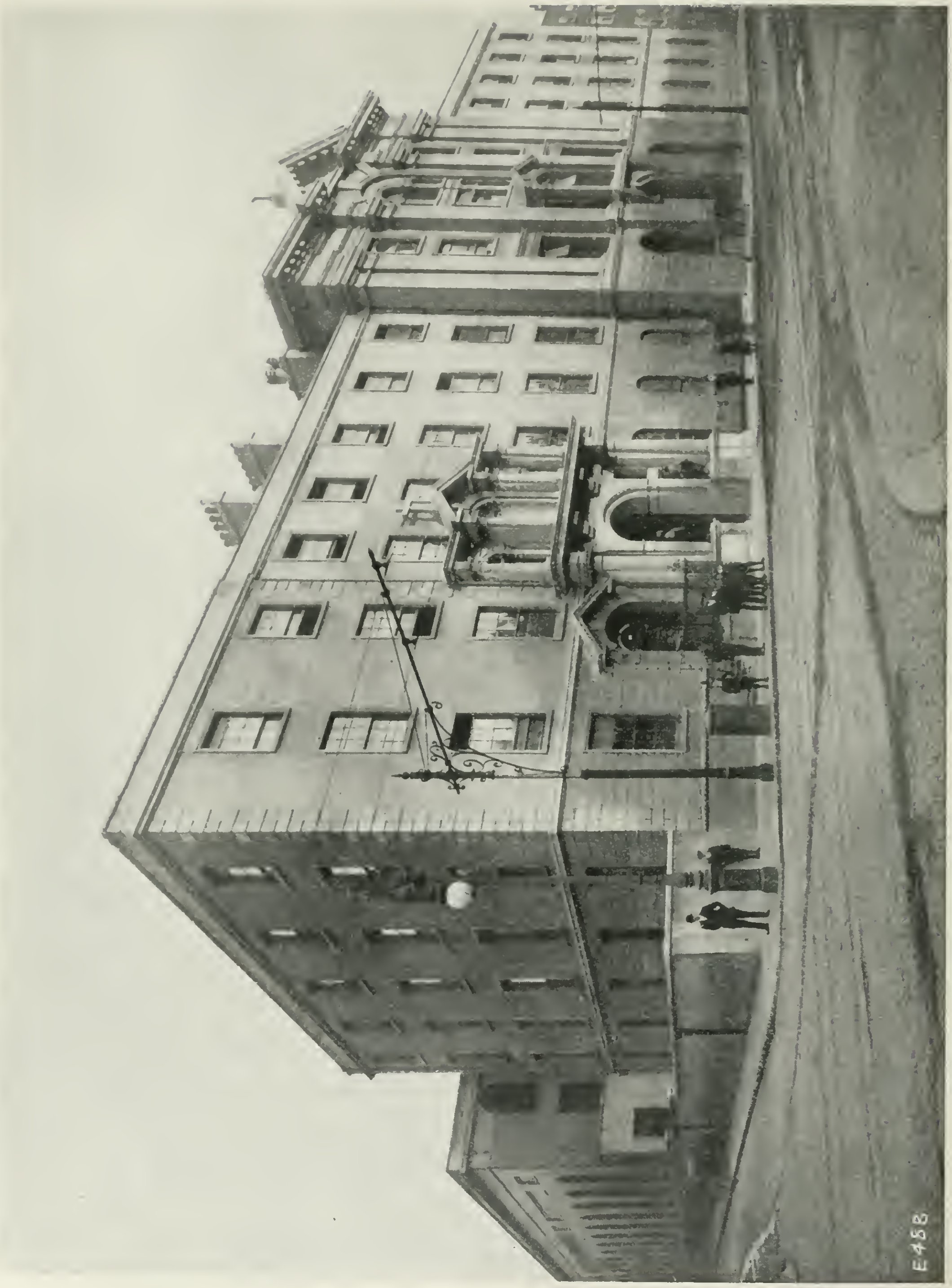
TOP FLOOR PLAN 10' 0" HIGH F TO C

NEW SODALITY AND CONFRATERNITY BUILDING, CARMELITE PRIORY, DUBLIN.

The parapets, crosses, and other projections generally are similarly reinforced.

The columns and piers throughout are reinforced with ¾-in. diameter rods, with bindings of 12 gauge galvanised wire at close intervals forming mesh work.

The external finishings are generally of two parts washed sand to one part of Portland cement, finished so as not to imitate stonework.



Exterior View.

New Sodality and Confraternity Building, Carmelite Priory, Dublin.

The internal finishings are of a plain substantial character, the principal floors being of oak blocks, and properly sound proofed, the ceilings of fibrous plaster in panels and patterns, and the walls plastered.

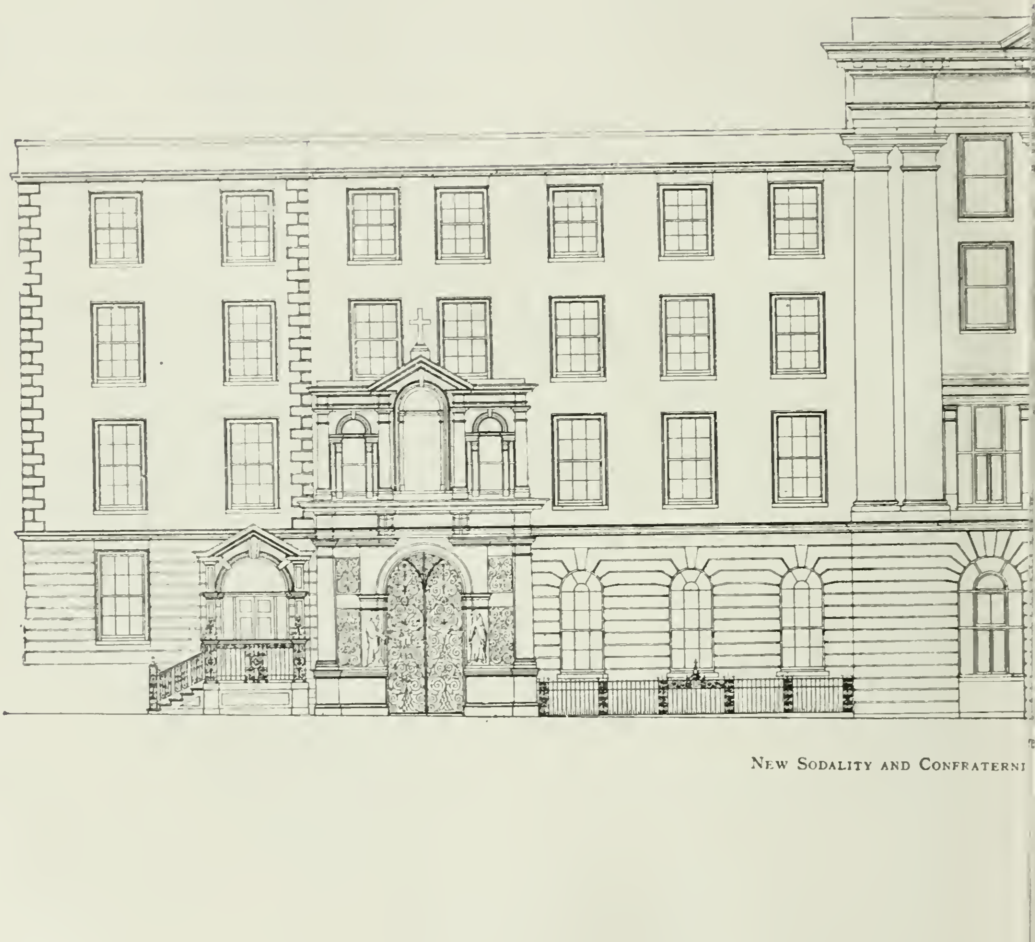
The equipment generally is very complete, electric heating being provided in addition to coal fires, electric light, private telephone service, lift, etc., the object being to reduce the cost of cleaning and service to a minimum.

The cost of execution of the concrete portions of the structure is between 2½d. and 3d. per cubic ft. of total contents.

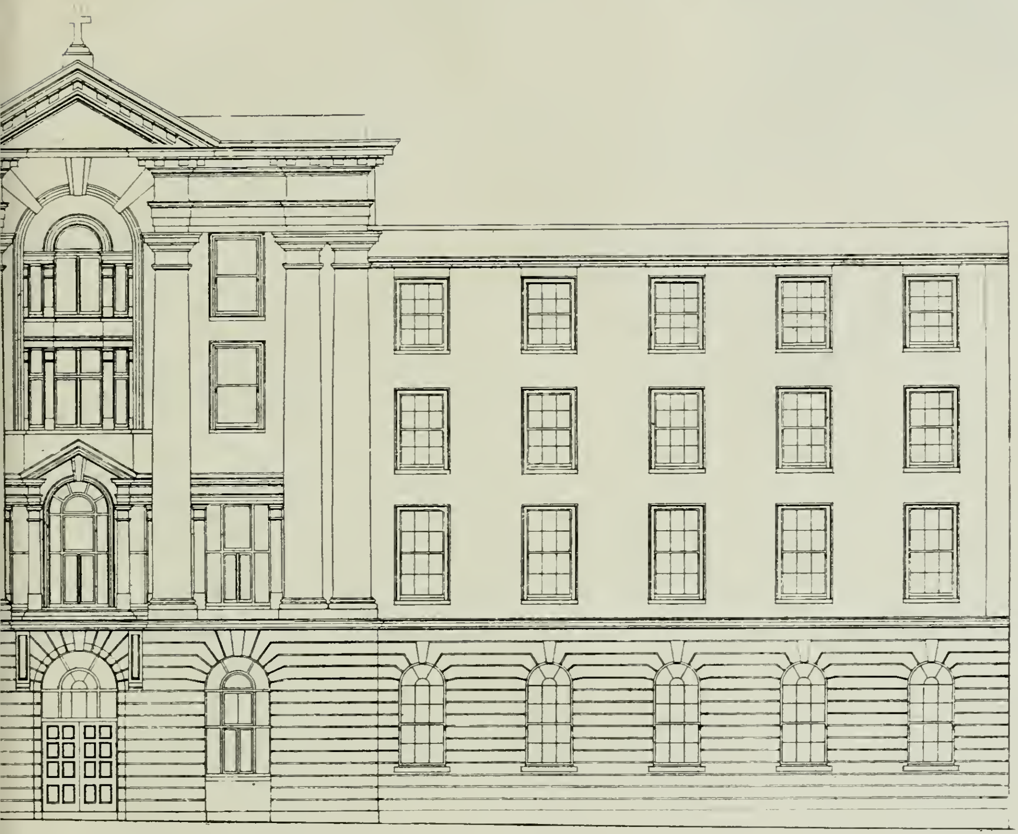
Although the building is in the centre of the area which was the scene of the recent conflicts and was struck many times, it sustained only very slight superficial damage.

The work has been executed by Sir Patrick Shortall, of Temple Street, Dublin, as general contractor, with Mr. Joseph Price as foreman, and all has been under the supervision of Michael J. Cullen, Esq., C.E., Surveyor, Building Superintendent to the Priory.

All the expanded metal reinforcement was supplied by the Expanded Metal Co., Ltd., of London and West Hartlepool.



New Sodality and Confraterni



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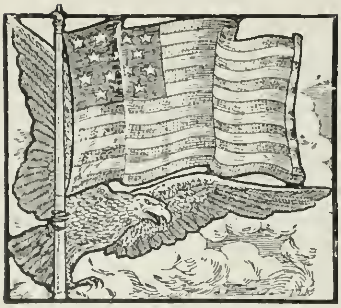


CONCRETE ROADS IN AMERICA.—OVER 3,000 MILES LAID IN THE PAST TWO YEARS.

A Review of the Papers presented at the Second National Conference on Concrete Road Building, held in Chicago in February, 1916.

By W. MATTHEWS-JONES, M.Inst.M. & Cy.E.
City Surveyor and Engineer of Chester.

INTRODUCTION.

Although concrete roads in America are a great and ever increasing success, yet if an engineer or road surveyor in England to-day talks of or recommends them he is looked upon as a crank or a fool by a great many, if not the majority, of his professional brethren. This leads one to ask the question why such should be the case, and an answer can be given in various forms and degrees. The first and foremost is that probably very few—comparatively speaking—engineers and surveyors in England have given much, if any, thought to the question of concrete roads. Again, if they have, they have not convinced themselves of the possibilities and benefits likely to accrue from the adoption of such roads. English engineers and surveyors, more especially road surveyors, do not care to try new things for fear of failures; and, of course, it frequently happens that members of county, borough, urban, or rural district councils have not very often the courage to back up their officials in carrying out experiments for similar reasons, and so having their legs pulled by the ratepayers whom they represent. The last consideration, and one which I think the most important, is that the Local Government Board and Roads Board have not openly at any rate shown any inclination to encourage road surveyors to experiment in the class of road construction known as concrete roads.

Dealing with the various aspects mentioned above anyone who has made a study of this question must feel that, although he has the greatest faith and would stake his reputation on this class of road or that, he is met by so many objections that he becomes downhearted, worried, and uncertain as to whether he is right or wrong.

At a certain engineering conference held recently one surveyor had the audacity to get up and tell his brother engineers that he had constructed several reinforced concrete roads in his area. At once questions were hurled at him from all over the room for information. One question particularly persisted in was: "What is the average tonnage over these roads?" And when he stated it was anything from 120 to 150 tons per working day of, say, ten hours, quite a titter went round the room, and one well-known engineer got up and said: "I suppose you mean 1,000 tons per day passes over the road?". This gentleman, I may mention, had a failure in the concrete road he had constructed, owing, in my opinion, to a want of knowledge of what he was asking the concrete road to do for him; in fact, I think the ballast material used in the first place was wrong, and, in the second place, to open a concrete road before it had thoroughly set, viz., eight days, for motor-'bus and other traffic which amounted to about 1,000 tons per day, was courting disaster, and through a failure of this description—unreasonable as it may be—some engineers and road surveyors became prejudiced against concrete road construction.

You must learn to walk before you can run. Give me the road surveyor who starts with concrete footways, then concrete back passages, and then goes on with concrete for light traffic or residential roads; who watches every aspect and condition of the work he has done, and by this means gains gradually an experience which ensures ultimate success.

WHAT ARE AMERICAN ENGINEERS DOING?

All this preamble leads up to what I want really to talk about, viz.:—What are American engineers and surveyors doing in this matter as compared with ourselves? and the answer is that, as usual, English engineers and surveyors are being left behind in modern road construction.

It has been my privilege and pleasure to read carefully the "Proceedings of the Second National Conference on Concrete Road Building" held at Chicago in February of this year, and the conclusions, etc., arrived at.

One notable fact about this conference is that, unlike other road conferences which I have attended in this country, nothing but concrete roads were spoken of, and any divergence from this was for comparative purposes only, whereas attend a road conference here in England, and you will note that there is no systematic consensus of opinion as to any one class of material which has been laid and successfully carried out, and this, in my opinion, is where the Local Government Board and the Roads Board fail. To make a success of anything a constant, systematic, unprejudiced, and conscientious study should be made of the subject, and this is what is undoubtedly done in America so far as concrete road construction is concerned; the betterment of road surfaces, not only as regards their wearing capabilities, but of their sanitary conditions as well.

Now, in England, if you attend a road conference, you will find an extraordinary difference of opinion on road-making, one advocating a water-bound macadam road; another says "Give me the same road, but tar-sprayed;" then it is demonstrated that neither of the above roads is good, and it is suggested that a tar-macadam or other bituminous bound road should be adopted. Someone who knows says, "I have tried water-bound and bituminous-bound roads, and all are bad—what I want is a granite sett paved road, a wood-blocked road, or a rock asphalte road, etc.;" and so this divergence of ideas goes on until a remark is made to the effect, "Give me any kind of a road, and I am satisfied." This sort of general discussion leading nowhere goes on year in and year out, and so it will continue until the Local Government Board or the Roads Board lays down some lines and gives the necessary monetary assistance to make proper trials, and have the engineering inspector, not only capable, but enthusiastic and practical in the particular branch of road-making and construction which he takes up. To do this and to put him upon his mettle to turn out the best he can irrespective of other classes should be a first consideration, for it is only by this means that we shall get to the rock bottom of the best class of road construction at a reasonable expenditure.

THE CONFERENCE.

In dealing with the proceedings of the Second National Conference of America on Concrete Road Construction it is difficult to know where to begin and where to end. All the recommendations are good and sound; the papers and discussions by eminent American engineers and road surveyors are to the point, and only the most useful information is given.

Now the first thing that they do is to lay down a brief summary of the fundamental principles which should be followed in the construction of concrete roads and place the same under the following headings, viz. :

1. Drainage of road bed is vital.
2. Subgrade must be of uniform density and should be compacted (which means, I take it, thoroughly consolidated).
3. Aggregates must be clean, hard and tough.
4. Fine aggregates (sand) should be coarse and well graded.
5. A rich mixture must be used.
6. Materials must be accurately proportioned.
7. Mixing must be thorough.
8. Sloppy concrete must not be used.
9. In general, reinforcement is justifiable.
10. Inspection must be intelligent and thorough.
11. Concrete must be prevented from rapid drying.
12. Pavements must not be opened too soon.

From the foregoing twelve headings it will be seen that practically every precaution has been taken to ensure a good job being turned out, and if I had time and space at my disposal I should like here to deal in detail with each of the recommendations laid down. I can, however, say this, that it will give me pleasure to supply individually or through this journal any information that is within my power or knowledge, so I will content myself by making a few remarks on what I consider the most important items in the twelve suggestions named :

1. The drainage of the road bed is of vital importance, and why? If the subgrade or strata is not well drained, there is the danger of unequal settlement or frost action, which will not only cause cracks, but settlements, and unevenness.

2. Aggregates must be clean, hard, and tough, and the fine aggregate should be coarse and well graded. I would add to this that the larger aggregate should not only be clean, hard, and tough, but it should be slightly porous and should not be brittle, and so inclined to grind away, and the sand should be free from salt and other impurities.

3. Materials must be accurately proportioned and the mixing thorough. Herein lies the secret of success, for if the proportions are not accurately and properly mixed there will be uneven mixing, which in concrete work is highly detrimental to success. Every particle of material should be measured in properly made gauge boxes—cement, sand, and other aggregate—and when such gauge boxes (which, by the way, should have bottoms) are showing signs of wear and tear they should be discarded and new boxes supplied, for, as a rule, the natural tendency is to put more sand and stone than cement. Every gauge box of material, when full, should be trammelled over to prevent excess, or another method which could be adopted is by having the separate aggregates measured in proportions by weight. Too much emphasis cannot be brought to bear upon this clause. The mixing should be regular and systematically carried out, and as much as possible by the same gang of men; otherwise, different gangs of men may have different ways of mixing.

4. Sloppy concrete must not be used. This is as detrimental in concrete work as concrete that is too dry, and here the judgment of the surveyor's representative or the clerk of works must decide, as it is useless to try and lay down any fast or rigid rule as to quantity of water to be used to each mixing. The weather conditions must be taken into consideration, for one day the atmosphere or weather may be damp or wet and another very hot and dry. During the former period less water should be used in the mixing and during the latter period more.

5. Inspection must be intelligent and thorough. Here again I would also add "constant," for I can assure anyone undertaking concrete work that it certainly pays to have a man in constant attendance whilst the work of proportioning, mixing, and laying is going on.

6. Rapid Drying.—Anyone having had experience of laying large bodies of concrete of no great thickness knows that in its drying process it has a tendency to contract or expand, and so many cracks are often caused, some more or less very discernible, others almost undefinable, and therein lies danger. When the concrete has set sufficiently for a man to walk upon its surface without in any way disturbing it, then it is time to commence the watering of the surface, not by flushing, but by means of a watering-can or small hose pipe with a rose at the end, and this must be continued in dry weather, not only through the day, but through the night; in fact, it is only experience that can teach one how much water in this respect is required. Wet sand upon the surface, as advocated by some, I do not agree with; sand can be made too wet, and so have a detrimental effect on the concrete underneath same.

7. Roads must not be opened too soon for traffic.—Of course, anyone who opens up a concrete road for traffic before it has thoroughly set is asking for trouble, and I can assure such engineer or surveyor he will not be disappointed in getting it. Judgment to a great extent must come into operation in connection with this part of the road work, but the engineer or surveyor can even help his judgment out here by having a fairly large slab of concrete made of similar thickness to that which he is laying on the side of his road, and, say, in ten or fourteen days cut through a portion of the sample to see how it is going on, and if not satisfied that it has set, then cut away another piece in a few days' time, and so keep on doing this until he is at last satisfied with its condition. Let me impress as fully as I am able the utter folly of opening a concrete road too soon after laying. Never mind the ordinary traveller grumbling and grousing about the delay, for if you do, and in a moment of anxiousness to please, open the road, you will find if such road goes wrong or to pieces, it is the traveller who has grumbled in the first place at the delay and inconvenience to himself that is the one to ridicule and criticise the folly of the engineer.

This, I think, deals generally with the principles laid down by the conference for guidance in the laying of concrete roads.

THE PAPERS PRESENTED.

I now propose to deal generally with the papers submitted to the conference, including a few remarks by the chairman, and hope to be as brief as possible in my remarks. This, however, is almost an impossibility to an enthusiast in this class of work, and I am only sorry that I have not more time and space at my disposal, for it is a subject full of interest, yet bristling with those difficulties that an engineer and surveyor loves to combat and finally overcome.

The Chairman's Address.

The Chairman of the Conference, Mr. W. F. M. Goss, Dean of the College of Engineering of the University of Illinois, states :—

> "That the character of the highways has always depended upon the nature and volume of traffic it is designed to sustain."

This is not only true in America, but also in England. The Indian was content with the trail made by his predecessor; the farmer in England was content with, shall we say, a trail, but of a broader nature. To-day to meet his requirements he must have, even off the main road, a better-laid occupation road to allow of getting his threshing machine and other heavier agricultural implements to his farm. Then, again, when he found that he could travel with his horse and wagon to a farther destination for the better disposal of his produce because of a more solid road having been laid, he naturally agitates for still better facilities for travelling. How much more, then, is it essential to provide good roads for motor and other mechanically propelled vehicles that have come into use during, say, the last ten years than it was when only horse traffic prevailed. Good sound roads, in my opinion, well and solidly constructed, requiring small annual repair charges, tend to increase the prosperity of a nation. Railway companies have seen this for years, and they have laid specially constructed roads to meet their requirements. So should every local authority throughout this country face the problem and face it right earnestly. When the war in which we are engaged is over—let local authorities and county councils consider this question—let them seek advice and come to the conclusion that the laying of concrete roads assisted by Government loans will be the means of saving our fellow-men (I mean the noble army of soldiers when they return from the fray) by finding work of this nature for many of them to do and which they can readily accomplish with a little training and patience, for to talk of repairing the water-bound macadam road to meet present-day requirements is now out of date and behind the time, and if the Local Government Board or Roads Board face this matter as they ought, and as I am hoping they will, the manhood of this country will not only be saved by an abundance of work being found for them, but healthier conditions will apply all round, and prosperity will follow in its wake. The chairman, in his address to the conference, gave the following striking figures, and they ought to convince the engineer and surveyor and other bodies of this country that concrete road construction is coming along at a grand pace and is coming to stay.

> "In the year following the first conference, which was held in 1914, 14,200,000 square yards of concrete highways, pavements, and alleys were built, an amount that was 40 per cent. in excess of that laid in the previous year, and which is equivalent to approximately 1,500 miles of 16-ft. roadway."

He then went on to say that—

> "Even in spite of the financial conditions of the country in 1915, some 15,000,000 sq. yds. of concrete roadway was constructed. The States of New York, Ohio, Wisconsin, and California each laid over one million square yards, and Michigan, Illinois, and Indiana each laid almost as much. The States of Delaware, Pennsylvania, and Mississippi made during this year their first extensive investments in concrete roads, all with the result that more than 3,000 miles of concrete roads have been built during the past two years."

Now, may I add, what further proof do English engineers and surveyors require to give them heart to follow in the steps of their cousins across the Herring Pond?

Increasing Public Interest in Road Improvement.

W. G. Edens, President Illinois Highway Improvement Association, gives a paper on "The Increasing Public Interest in Road Improvement." This paper, though short, is full of praise for concrete road construction, and he states—

> "That now the pioneer work of concrete road construction has been done by the Wayne County and Milwaukee, he, as representing the Associated Good Roads Committee of Chicago and Cook County, would like to say that they have now got $2,400,000 for the construction of concrete highways."

He also states that they have expended their first allotment of State aid and have the realisation of 20 miles of concrete highways, 18 ft. wide, which, as he modestly says,

> "I think will be found to be equal, if not superior, to those in the Wayne County and Milwaukee, because we started after them and have had the benefit and advantage of their experience."

The Building of America's Highways.

In dealing with the next paper by Henry B. Joy, President of the Lincoln Highway Association, on "The Building of America's Highways," I shall content myself by quoting two paragraphs only, as in my opinion they speak for and commend themselves without any comment.

> "There is no greater economic waste in the United States to-day than the poor roads over which nearly all traffic, especially the product of farms, must be hauled in wagons or motor vehicles before it can be transported by train. The figures representing this loss are almost too enormous to understand. The Wayne County (Michigan) Highway Commission, through Edward N. Hines, chairman, has stated in one of its annual reports that the County could better afford to build concrete roads, because, as compared with accepting any kind of macadam road as a gift, if they had to pay for the upkeep, they would have money in the bank at the end of the eight years.
>
> "This is a very strong statement to make, but I know Mr. Hines well; he is a conservative man, one of the best Highway Commissioners in the United States. He has the facts and records to establish the correctness of assertions which he makes."

I now pass over some of the papers as not being likely to prove interesting for the purposes of any discussion that may arise from the few notes I am making of the Conference, although the paper read by Major Amos A. Fries, Corps of Engineers, U.S. Army, on "The Value of Permanent Highways for National Defence" is as interesting as any of the other papers. He deals more or less with roads from a military standpoint, commencing his discourse with remarks on roads constructed by King Cheops, the great pyramid builder of Egypt, who built a great road 2,000 years before Christ, and which road is said to have taken 100,000 men ten years to construct, and so from ancient history he comes to the present day, carrying us with him through the various stages of road construction adopted by different people in different ages. As an example of historical notes and present day methods of how and where to construct roads his paper is in my opinion unique.

Maintenance Bonds for Concrete Roads.

We now come to a paper read by Edward Hoopes, of the Fidelity and Deposit Co. of Maryland, on "Maintenance Bonds for Concrete Roads." This paper deals entirely with maintenance clauses, some of which should be inserted in all contracts for the construction of concrete roads, and the advice he gives is valuable without a doubt and will well repay those who read it who have any idea of constructing concrete roads, as to what forms of maintenance and guarantees should be placed in a contract for such work.

Motor Haulage and Good Roads.

The next paper of interest is that by S. M. Williams, of the Garford Motor Truck Co., on "Motor Haulage and Good Roads." In this paper we get the opinion of an expert on motor haulage, and the valuable suggestions given by this writer makes the paper well worth reading. For instance, he states—

> "The greatest incentive for permanent road construction is the feeling on the part of the public that they are getting their money's worth through judicious expenditure. The day is past when the motor truck is looked upon as an experiment. Motor truck haulage and good roads are inseparable. The motor truck not only depends upon good roads, but they must be permanent such as the concrete roads."

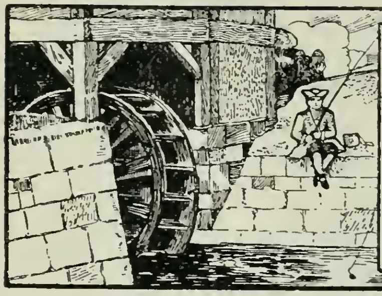
He practically brings his paper to a close with the following paragraph:—

> "I do not believe that as an industry we have any right to advocate the building of any particular type of road, further than that they be of a permanent character. I am glad to say, however, that I believe when a motor truck or motor car owner hears of concrete road construction he is insured of permanency and dependability, and especially when he follows the progress of concrete road construction during the last few years."

(To be continued in next issue.)

NOTE.—One of the most important and interesting papers was the one read by Mr. H. S. Van Scoyoc, Chief Engineer to the Toronto and Hamilton Highway Commission, on "Concrete Highways Subjected to Extremes of Temperature," and as it is intended to publish this paper in full at a later date, no further reference to it is made in this review.

A CONCRETE ROAD IN WISCONSIN.

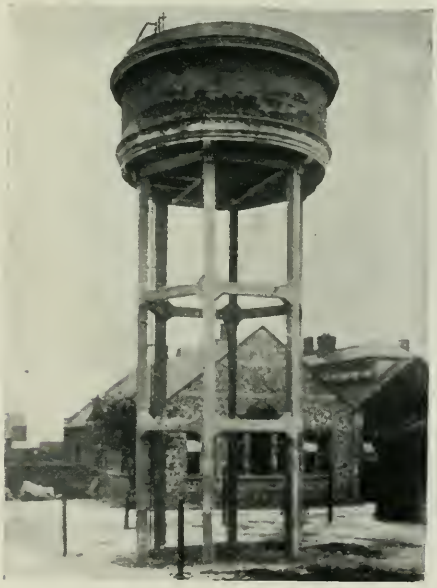


ILLUSTRATIONS OF REINFORCED CONCRETE WATER TOWERS.

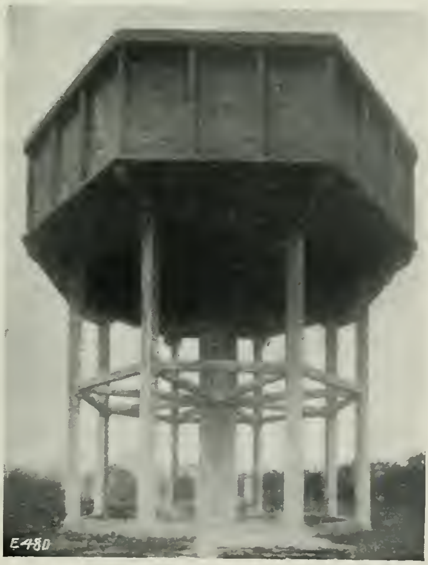
In the following pages we give a series of illustrations which show the application of reinforced concrete to water tower construction. The illustrations comprise some examples brought to our notice and of which fuller details have appeared in earlier numbers; and we have also succeeded in presenting a few illustrations and particulars of works not previously dealt with by us.

The examples of the different systems of reinforcement used have been taken in alphabetical order.—ED.

THE advantages of reinforced concrete for water towers and similar structures are so well known to our readers that it is not necessary for us to enlarge upon this point here. The material has been extensively used for this purpose by engineers in all parts of the world, and in presenting these few examples we



WARRINGTON UNION WATER TOWER.



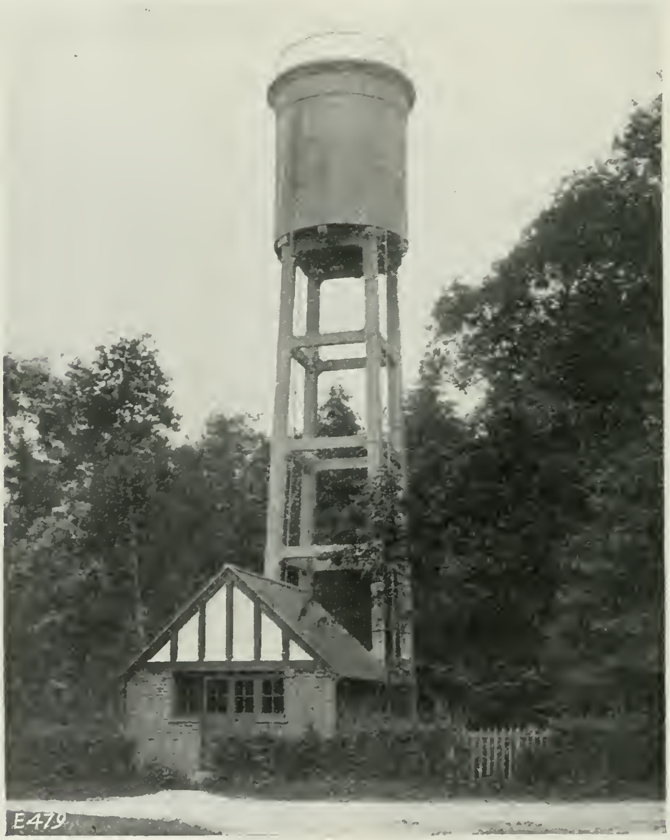
WATER TOWER AT WHITBY, NEAR CHESTER.

are only giving a very slight indication of the extent to which this form of construction has been employed for this particular class of building.

Warrington Union Water Tower.—Has a capacity of 15,000 gallons. The height to the under side of the tank is 40 ft., and the depth of the water is 10 ft. 6 in.

The architects were Messrs. Segar and Owen, and the contractors were Messrs. W. and A. Ashton, of Warrington.

Whitby, Chester.—This tower was erected for the West Cheshire Water Co. Capacity: 200,000 gallons; height to the under side, 42 ft.; depth of tank, 13 ft.; diameter (diagonal), 57 ft. Engineer, Mr. Isaac Carr, M.Inst.C.E., and the contractors were Messrs. I. G. Davies and Co., Frodsham.

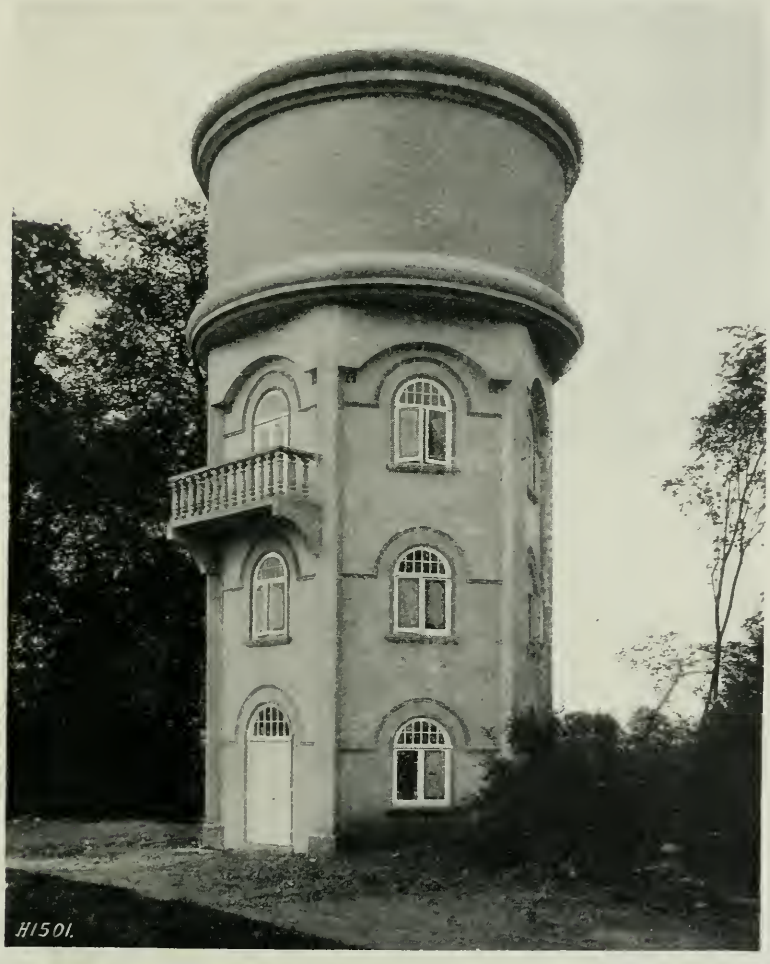


WATER TOWER AT BROOKMAN'S PARK, HATFIELD.

Brookman's Park, Hatfield.—Capacity: 10,000 gallons. Height to the under side of the tank, 50 ft.; depth of tank, 14 ft.; diameter, 12 ft.

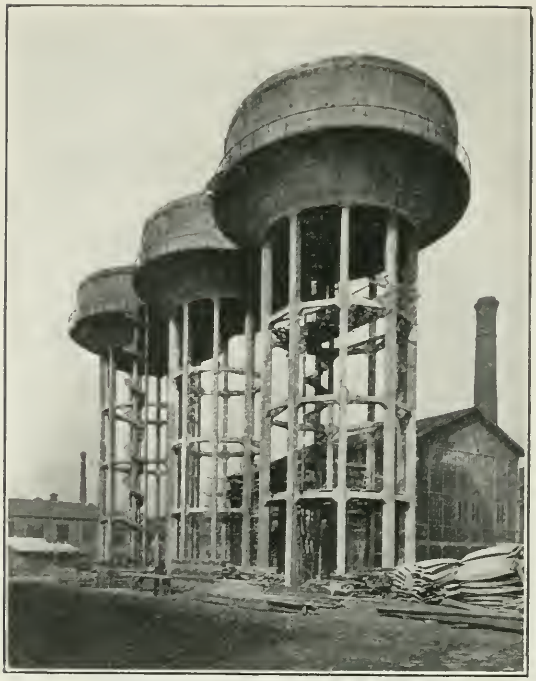
The reinforcement in these three examples was B.R.C. Fabric.

* * *



Reinforced Concrete Water Tower, Burton-on-Trent.

Burton-on-Trent.—This water tower was erected in 1914 at Rolleston-on-Dove, near Burton-on-Trent, to deal with the water supply for the village. It has a capacity of 45,000 gallons and a total height of 52 ft. The cylinder has a diameter of 25 ft. The engineer for the work was Mr. John Frith, of Baslow, Derbyshire.



WATER TOWER, LANDY, NEAR PARIS

Landy, near Paris.—This is a group of three water towers erected for the "Société du Gaz de Paris," at Landy, near Paris. Two of the tanks contain 600 cubic metres (about 130,000 gallons) and the third 500 cubic metres (about 110,000 gallons). The towers are about 70 ft. high above ground level.

The bottom of each tank is in the shape of a dome 3 in. in thickness, the walls of the tanks are supported by a circular cantilever 6 in. thick. The dome covering of each tank has a thickness of only 2½ in.

The two spiral staircases are also in reinforced concrete.

Bristol.—This reservoir was erected for the Bristol Electrical Department and has a total capacity of 150,000 gallons and a diameter of 56 ft. Height, approximately, 12 ft. and the thickness of walls varies between 6 in. at the bottom and 4 in. at the top. Contractors, Messrs. Wm. Cowlin and

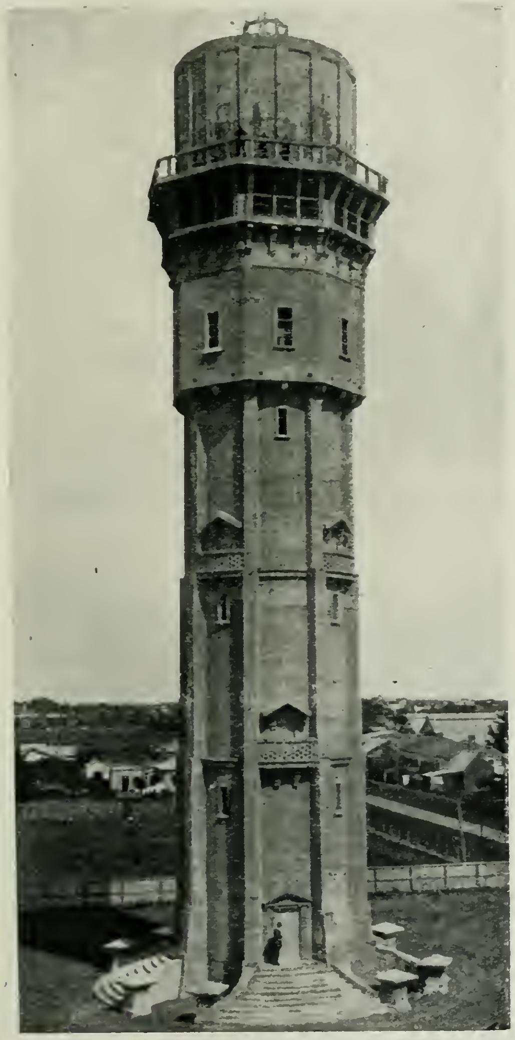
WATER RESERVOIR, BRISTOL ELECTRICAL DEPT.

Son, Bristol, who did the work under the supervision of the Engineer of the Bristol Electrical Department.

The Coignet system of reinforcement was adopted in these three examples.

* * *

Hawera, N.Z.—The origin of this water tower is of interest, as prior to its erection the town of Hawera had to depend on water mains alone for fire prevention purposes, and these proved quite inadequate. To remedy this the tower was built. It includes two tanks, the upper one having a capacity of 100,000 gallons and the lower one half this amount. Internal diameter of tower and lower tank is 25 ft., internal diameter of upper tank 30 ft., height of structure to top of concrete 166 ft. Highest water level 153 ft. from ground. The engineer responsible for the design and structure was Mr. J. C. Cameron.



WATER TOWER, HAWERA, N.Z.

BEACONSFIELD WATER TOWER.

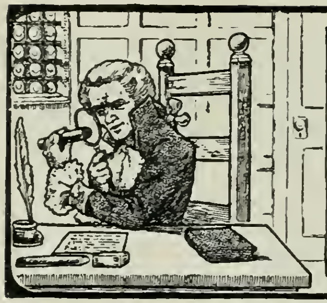
Beaconsfield.—The tower is situated on the Grange Estate and has a capacity of 7,000 gallons. Total height above ground is 43 ft. The tank is supported on four columns; the lower portion has been enclosed and forms an engine room. Consulting engineers, Messrs. Hal Williams and Co., London.

Old Mill Water Tower, Aberdeen.—Erected to provide an efficient safeguard for the Poorhouse buildings in case of fire. The building is 43 ft. square and 12 ft. 6 in. deep over all, and is elevated 20 ft. above ground level. Capacity 110,000 gallons, divided into two compartments, with a common inlet chamber. Engineers, Messrs. Walker and Duncan, C.E., Aberdeen.

In these three last examples the Indented Bar system of reinforcement was used.

OLD MILL WATER TOWER, ABERDEEN.

(To be continued.)



RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

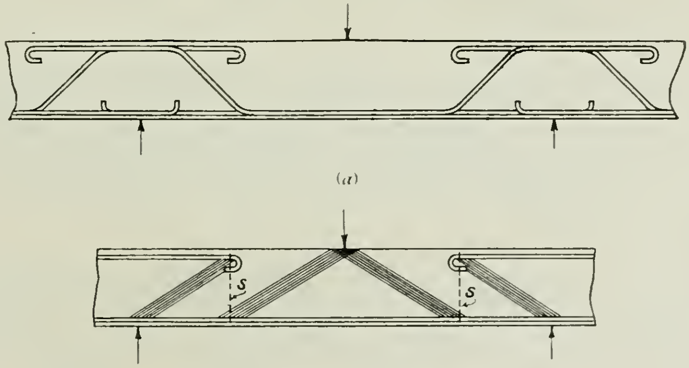
Continued from August issue, p. 423.—ED.

PART III (*continued*).

(*b*) *STATEMENT OF THE WRITER'S THEORY* (*continued*).

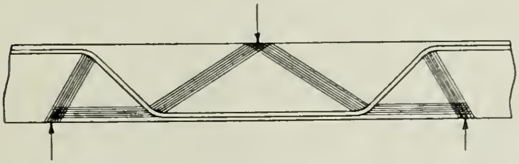
14. *Indirect inclined compressions.*

It has been shown that in continuous beams the value of *direct* inclined compressions in resisting shear is frequently small. This, however, does not prevent the value of *indirect* inclined compressions being great. Consider the arrangement of bars in *Fig.* 32 (*a*) which is a very common one.



(*a*)

(*b*) System 1.



(c) System 2.

FIG. 32. INDIRECT INCLINED COMPRESSIONS.

For purposes of analysis we may divide this up into systems 1 and 2 as shown in *Figs.* 32 (*b*) and (*c*), and fill in the inclined compressions shown, which will enable the reinforcement to act as a truss.

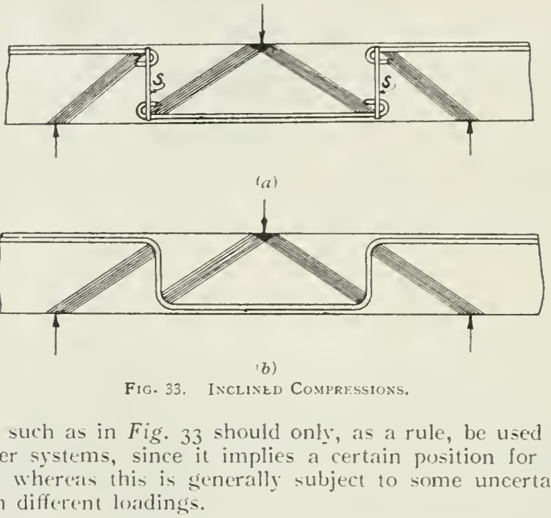
A careful consideration of these inclined compressions teaches several lessons in the design of reinforced concrete members, which are difficult to realise otherwise. Notice first that system (2) is complete in itself, and the stress in each member is easily determinable by the method of sections or by a funicular polygon.

Note, then, that system (1) is only complete if the stirrup S is provided, and made adequate. This is a very important result, because it shows that stirrups are an integral part of any system in which the bars, without being taken from one flange to the other, are stopped off between the support and the load.

Yet the arrangement is sometimes used without stirrups, showing that some designers do not appreciate this point. They probably hardly realise that they are relying on the tension of the concrete, since they use the system in combination with a system of bent-up bars, in which a stress of 16,000 in the steel must necessarily mean hair cracks in the concrete, after which its value in tension is, of course, nil.

The same point is illustrated in *Fig.* 33 (*a*), where the stirrup is an integral part of the system—except in the case of slabs where the diagonal tension in the concrete can take the *whole* shear.

Note that a bent-up bar, as in *Fig.* 33 (*b*), has the same effect, and is in the writer's opinion much better, since there is less likelihood of the bar being seriously displaced when concreting. Note also that the stirrup also serves to resist the tendency of the hooks to open.



(*a*)

(*b*)

FIG. 33. INCLINED COMPRESSIONS.

A system such as in *Fig.* 33 should only, as a rule, be used in combination with other systems, since it implies a certain position for the point of contraflexure, whereas this is generally subject to some uncertainty, and to variation with different loadings.

Note also that if the bent-up bar in *Fig.* 33 (*b*) is inclined as in *Fig.* 32 (*c*), this latter difficulty is partly removed, since with this system the point of contraflexure may vary between the points *a* and *b* without causing the system to be incomplete.

15. *Maximum shear in a beam.*

It was shown in sections 2, 3, and 4 how to calculate the resistance to shear of beams reinforced with stirrups and bent-up bars.

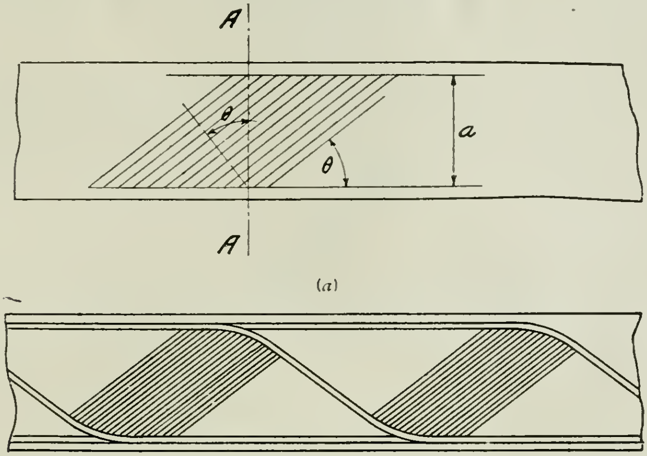
It was assumed, however, that failure would take place in the steel, whereas it is obvious that if the area of bent-up bars or of stirrups is increased sufficiently failure will take place by the compressive stress caused by these members on the concrete. Hence it is necessary to determine a limiting value to the safe shear in a beam of a certain size, *however heavily reinforced in shear,* and it is the object of this section to attempt this. If we consider any vertical section, resistance to shear will be due to inclined compressions crossing this section—whether direct, due to stirrups, or due to bent-up bars, matters not, or to inclined tensions crossing it.

Considering the inclined compressions first, let them be inclined at an angle θ to the horizontal (see *Fig.* 34 (*a*)) in a beam in which the radius arm of the flange force is a.

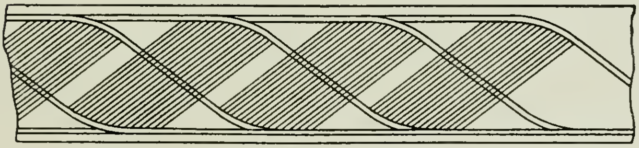
Then the width of the belt of the inclined compressions which cross any particular vertical section is—

$$a \cos \theta$$

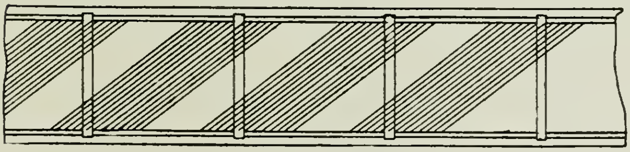
Hence, taking b as the breadth of the beam, and c the permissible stress in the concrete, we have the limiting value of the inclined compression crossing the plane as—



(*b*) Single System of Inclined Bars.



(*c*) Double System.



(*d*) Stirrups.

Fig. 34. To Illustrate Limiting Values of Shear.

$$C = a\ b\ c \cos \theta$$

and its vertical component available for resisting shear is—

$$S = a\ b\ c \cos \theta \sin \theta \quad . \quad . \quad . \quad . \quad (1)$$

This is a maximum when $\theta = 45^\circ$, where $\cos \theta \sin \theta = \frac{1}{2}$. Hence we may write—

$$S_{\text{max.}} = \frac{a\ b\ c}{2}$$

or putting—

$$c = 600$$

$$S_{\text{max.}} = \underline{300}\ a\ b$$

This is an extremely important result, and shows that across any vertical plane devoid of inclined bars the shear may never exceed 300 *a b.*

Consider now the bent-up bar in 34 (*b*).

If its resistance is not limited by its own strength it will be limited by the inclined compressions in the concrete in the adjacent panels, which clearly have to resist the same shear as the bar.

Hence we have the important result that—

The resistance of bent-up bars must never exceed a b c cos θ *sin* θ, *or* 300 *a b if* θ *is* 45° *and c is* 600.

Consider now the difference between the arrangement in 34 (*b*) and (*c*).

In the former the shear is carried by inclined compressions in one panel, inclined tension in the next, and so on alternately. This system is characterised by a bent bar every other panel, and is known as a single system of bent-up bars. Since the steel and the concrete each have to carry the whole shear, we see that—

In a single system of bent-up bars the resistance is limited to 300 *a b, or less where* θ *is not* 45°.

In 34 (*c*) any vertical section such as *A A* is cut by inclined compressions and tensions, and as each may have a resistance equal to 300 *a b*, we have that—

In a double system of bent-up bars the resistance is limited to 600 *a b or less when* θ *is not* 45°.

Since the whole resistance of stirrups is due to inclined compression, we have—

resistance of stirrups is limited to 300 *a b.*

Note that if a system of stirrups, as in 34 (*d*), is superimposed on a single system, as in (*b*), the inclined compression will be superimposed, and the limiting value is not increased.

In a system carried partly by stirrups and partly by a single system of bent-up bars, the resistance may never exceed 300 *a b.*

The effect of a superimposed stirrup system on a *double* bent-up system is to reduce the proportion of shear carried by the bent-up bars, and it may be shown that in a system carried partly by stirrups and partly by a double system, the resistance may never exceed—

$$300\,a\,b\left(1+\frac{S_b}{S_s+S_b}\right)$$

where S_b is shear taken by bent-up bar system
S_s ,, ,, stirrup system.

It will be seen that this gives 300 *a b* when stirrups take the whole and 600 *a b* when the double system takes the whole.

In the foregoing it has been assumed that the compression stresses were uniformly distributed across the width and breadth of the belts in which they act, and it remains to consider how far this is the case.

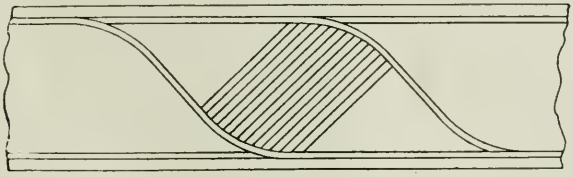
In *Fig.* 35 (*a*) are shown bent bars gently bent, in which the compression is well distributed across the panel, while in 35 (*b*) the bend is so sharp that this cannot be the case.

It is still not realised by many experts that (*b*) is bad and that (*a*) is essential if higher values of $\frac{S}{a\,b}$ are to be safely resisted. Where the bends are made as at (*b*), the foregoing safe values for $\frac{S}{a\,b}$ must be considerably reduced.

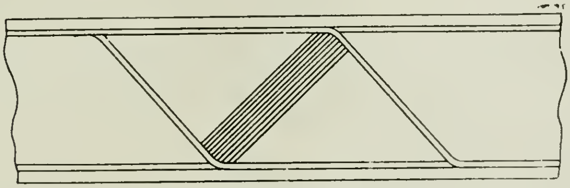
Consider now 35 (*c*), a section through beam showing the distribution laterally. It is obvious that though the pressure may be approximately uniform half-way down the web, it will be much more intense at the surface of the bars.

This applies equally whether stirrups or bent-up bars are under consideration.

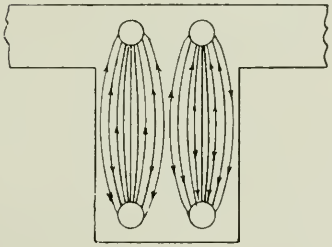
It may be thought that the effect of this would be that the effective width of the beam should be reduced to the sum of the diameters of the bars and the stress taken on this area only, but both experience and theory indicate that it is not necessary to go as far as this.



(*a*) Bent Bars Gently Bent.



(*b*) Bent Bars Sharply Bent.



(*c*) Distribution of Pressure across Width of Beam.

FIG. 35. DISTRIBUTION OF INCLINED COMPRESSION.

Consider *Fig.* 36.—When the pressure is uniform on the whole width, as at (*a*), failure will occur along a plane inclined at an angle θ and the resistance will be proportional to the length $c\ d$, which is—

$$\frac{b_1}{\cos\theta}=P_1$$

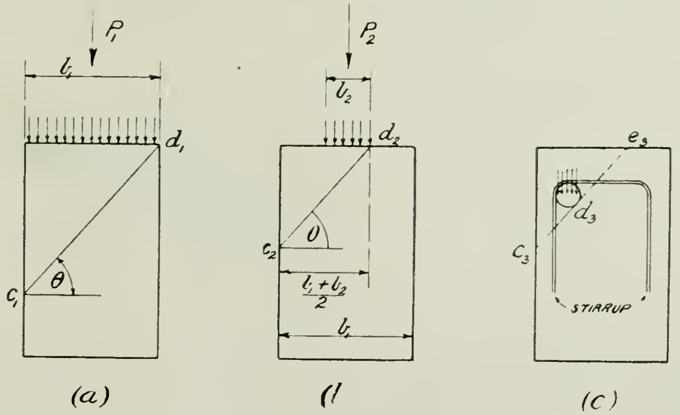


FIG 36. TO SHOW THE EFFECT OF LOCAL PRESSURE.

If the pressure is concentrated on a small central area of width b_2 the resistance will be proportional to the length $C_2\ d_2$, which is—

$$\frac{b_1+b_2}{2\cos\theta}=P_2$$

Hence—

$$\frac{P_1}{P_2}=\frac{b_2}{\frac{b_1+b_2}{2}}$$

In other words the concrete in case (*b*) behaves as if the width is neither *b* or not *b*, but the mean of the two—

$$\frac{b_1+b_2}{2}$$

Consider now 36 (*c*) showing the bar acting, as in practice, within the concrete. The effect is that not only has failure to occur along the plane $c_3\ d_3$ as before, but the resistance of the portion $d_3\ e_3$ or some other plane is called into play also, which has the effect of adding further to the safe pressure. If the stirrup as indicated on the drawing is provided it will further prevent failure across the plane indicated.

Taking all these factors into account, we see that a much higher local stress on the bars than 600 is perfectly permissible. The writer is of opinion that where the sum of the diameters of bars is equal to at least one-third the width of the web a stress of 600 across the web is permissible where stirrups going across from one bar to the other laterally are provided.

If the sum of the diameters is less than one-third of the width of the web, the writer would take three times the sum of diameters of the bars as the effective width of the web.

Of course, only the bars side by side are considered, and not those above one another.

This is equivalent to allowing a local pressure on the bars of 1,800 lb./in.².

16. *Two inclined compressions superimposed.*

It sometimes happens that in a beam two inclined compressions of different slope may be superimposed. For example, a *direct* inclined compression from support to load may cross an *indirect* inclined compression produced by stirrups or bent-up bars. The latter will always be more inclined to the vertical.

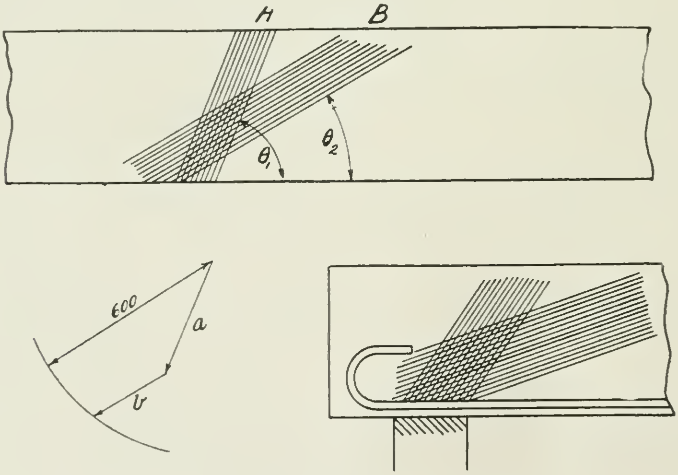


FIG 37. Two Inclined Compressions Superimposed.

The treatment of such cases is as follows :—

Where stress in the concrete in the web is not the limiting factor, the shear resistance due to the two may be added in full and no trouble arises.

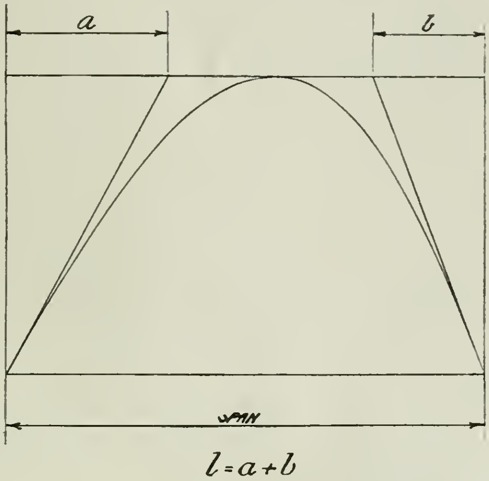


FIG. 37*a*. TO SHOW HOW TO FIND *l* FROM THE DIAGRAM OF MOMENTS *(see Section 17)*.

Where, however, concrete stress in the web *is* the limiting factor, take the shear due to the steeper compression in full. If this stresses the concrete up to 600 the resistance of the lesser inclined must be neglected. If, however, it does not stress fully up to 600, calculate how great a stress may be permitted along the less inclined direction to give 600 as the resultant of the two, and allow the resistance to shear of this portion only, added to that of the more inclined compression.

Thus in *Fig.* 37 a steep compression " *A* " crosses a less inclined compression " *B*."

To calculate the resistance of this action of the beam to shear, calculate the stress *a* due to " *A* " and allow this in full up to a limit of 600.

If it is less than 600, set it down to a scale as shown, and with one end as centre draw an arc of a circle having 600 as radii. Then from the other end draw *b* parallel to *B* till it meets the arc, which will give the permissible stress in *B* which will not overstress the concrete.

This method of giving preference to the steeper compression gives the maximum resistance.

An example is given in Part IV. (see next issue).

It may be mentioned that where the lozenge 1, 2, 3, 4 subjected to the two stresses occurs near the support only, a combined stress of more than 600 is sometimes permissible, since the support gives lateral support and prevents lateral bursting.

Note that if instead of adding the compression stresses vectorially, as above, we add them arithmetically, the calculations are greatly simplified and the error is on the side of safety. The error is small where the inclinations vary by less than 45°.

17. *Résumé of calculations of inclined compressions as affecting beams, with simple rules and formulæ.*

It will be convenient here to gather together a few of the results now obtained in the preceding articles.

Where steel is provided on tension side only $n = 3d_1$ and

$$S = 1{,}800\ a\ b\ d_1 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

if—

$$c = 600$$

when, further—

$$a = 0{\cdot}88\ d$$

$$d_1 = 0{\cdot}12\ d$$

this reduces to—

$$S = \frac{190\ b\ d^2}{l_1} \text{ or } \frac{150\ b\ h^2}{l_1} \quad . \quad . \quad . \quad . \quad (2)$$

To justify this value the steel in tension must have an area of not less than—

$$A = 0{\cdot}006\,b\,h = 0{\cdot}00675\,b\,d$$

or—

$$p = 0{\cdot}675 \text{ per cent.} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

carried to the support and provided with a *fully* efficient hook or fastening (see sections 6-8).

Where steel is provided on both sides—

$$n = 0{\cdot}75\,h$$

$$S = \frac{225\,b\,h^2}{l_1} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

To justify this value the steel in tension must have an area of not less than—

$$A = 0{\cdot}014\,b\,h \text{ or } 0{\cdot}0155\,b\,d$$

or—

$$p = 1{\cdot}55 \text{ per cent.} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

carried to the support and provided with a *fully* efficient hook or fastening (see section 11*a*, p. 418, August issue).

The above formulæ are applicable to free and continuous beams. If free the specified area of steel must all be on the lower side, assuming a downward load, when (2) is used, and if formula (4) is used $A = 0{\cdot}012\,b\,h$ on the lower side, and at least half as much on the opposite side in addition.

If continuous, the specified area of steel must be divided between the top and bottom in the same ratio as the support moment and centre moment are to each other.

Thus if we have—

$$M_s = \frac{W\,l}{12} \text{ and } M_c = \frac{W\,l}{24}$$

$$\text{then top steel} = \tfrac{2}{3}\,A$$

$$\text{bottom steel} = \tfrac{1}{3}\,A$$

A being the area required by formulæ (3) or (5).

If—

$$M_c = \frac{W\,l}{12} \text{ and } M_s = \frac{W\,l}{24}$$

$$\text{then top steel} = \tfrac{1}{3}\,A$$

$$\text{and bottom steel} = \tfrac{2}{3}\,A$$

If the same beam, ***both*** these conditions may apply under different loadings, both top and bottom steel must be equal, $\tfrac{2}{3}\,A$.

If the requisite area of steel is not provided or carried right through (measure it at its *least* section), S must be reduced in proportion between what is provided and what required.

In the preceding formulæ l_1 is the sum of the two distances from the supports to the points where the tangent to the bending moment diagrams at the ends cuts a horizontal line drawn through the point of maximum moment (take free moment in continuous beams). See *Fig.* 37*a*, $l_1 = a + b$.

For single concentrated load ... ... $l_1 = \text{span}$

For uniform load ... ... $l_1 = \dfrac{\text{span}}{2}$

For point-loads at the third points ... ... $l_1 = \dfrac{3}{2}\text{ span}$

As the line of inclined compression is the bending moment diagram drawn very flat to lie within the section, the values given for S apply at the end where the shear is greatest, and fall off as the shear falls off.

Thus, for single concentrated load S is constant from support to load.

For two symmetrical loads S is constant from support to first load and zero between them.

For uniform load, S falls off uniformly to zero at mid-span.

Where other inclined compressions intersect the direct inclined compression where the stress is high—*i.e.*, at load or support—the value of S given by formula (2) or (4) must be reduced so that the stress of $c=600$ is not exceeded (see par. 16).

With this proviso, the shear by direct inclined compression may be added to that by stirrup s or bent-up bars.

However heavily reinforced, the safe shear across a section can never exceed $S=300\ b\ a$ where stirrups alone, or a single system of bent bars alone, take the whole load.

And can never exceed $S=600\ b\ a$ where a double system of bent bars carry the whole load.

With a combination of stirrups and a single system of bent-up bars $S=300\ b\ a$ can never be exceeded.

With a combination of stirrups and a double system of bent-up bars, a value between $S=600\ b\ a$ and $S=300\ b\ a$ can never be exceeded.

If θ is different from 45°, or if a direct inclined compression takes part load, the above values have to be reduced.

Beams should not be designed for a section less than corresponds to $S=200\ b\ a$ or more except by a scientific designer of experience.

(*To be continued.*)

MEMORANDUM.

Water in Concrete Mixtures.—H. Colin Campbell, in discussing the subject of what amount of water should be used in concrete mixtures, in the *Scientific American,* comes to the conclusion that about 25 per cent. of water gives the strongest mixture. He says:

"Although the tendency is now to use wetter mixtures for concrete than prevailed in general practice some years ago, there is still a controversy among self-styled authorities, engineers, and contractors, as to the proper consistency for concrete mixtures. In most cases the amount of water used has represented the arbitrary opinion of the engineer or person in responsible charge of the construction.

"In reinforced concrete work there is no question but that wet mixtures facilitate placing the concrete in intimate contact with the reinforcement, but in reinforced work there is a possibility that too much water will be used, so that after the process of crystallisation has been completed in the cement, an examination of the concrete would show pockets or voids along the reinforcement.

"The average contractor, simply for his own convenience, will frequently use more water in his concrete than necessary, because a wet mixture facilitates spouting and consequently saves time and money in placing expense.

"As in all things there must be a happy medium, so in concrete it is evident that the advocates of dry mixtures and the advocates of wet ones cannot both be correct. Tests have been recorded of experiments made in the Engineering Testing Laboratory of the Sheffield Scientific School, Yale University, involving experiments based on 1 : 2 : 4 mixtures, used with varying percentages of water. Conclusions based on these tests showed that concrete mixed with 27½ per cent. of water developed at the end of thirty days a maximum resistance, both to tension and compression, in comparison with mixtures made with other percentages of water. In other words, these scientific experiments pointed to the fact that there is a definite limit to the amount of water that should be used, and that this limit is much below that generally used in most construction.

"Another interesting point brought out by the tests referred to was that to attain corresponding strength in mixtures using 30 per cent. and more of water, an increase of 5 per cent. upward in materials was required to equal the results shown by the mixtures containing 27½ per cent. water.

"This means that for concrete to meet certain test requirements the contractor may give himself a margin of 5 per cent. or more for profit by adhering to the 27½ per cent. content of water."

RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

AMERICAN WATERWORKS ASSOCIATION.

WATERWORKS RESERVOIRS.

By DABNEY H. MAURY.

(*Continued from August issue, page 440.*)

SOME CONSTRUCTION DIFFICULTIES AND SOME SUGGESTIONS.

THE first thing naturally demanded of a waterworks reservoir is that it shall hold water, and as a rule the most difficult part of the construction of a reservoir is making it watertight.

A small amount of leakage really does no great damage; but so long as any leakage can be detected it is an eyesore, and it remains as a reproach to all of those in any way connected with the design or construction of the reservoir, whether contractor, engineer, or owner. For these reasons, leaks so small that they could do no harm whatever are not as a rule permitted in the finished structure, even though the cost of stopping them is out of all proportion to the value of the water lost.

It was the writer's good fortune that in all of the reservoirs mentioned in this paper he had to deal with contractors who endeavoured honestly and conscientiously to secure good results. In almost every case they succeeded remarkably well, and when they failed, the failure was due to some oversight or bad judgment on their part and not to any desire to skimp the work.

It is not an easy matter to build a reservoir which shall be absolutely watertight from the time the forms are removed. Fortunately, however, very small leaks will usually become less or " take up " in a short time, especially when the stored water contains iron or sediment, and in most cases it is not very difficult to stop large leaks, or at least to reduce them to so small an amount that they will ultimately stop of themselves.

Fig. 6 is a construction photograph of the 2,000,000-gallon reservoir already mentioned, and shows the bottom completed and the vertical channels for supporting the reinforcing bars already in place, with over half of these bars fastened to the channels. These channels served another useful purpose in that they afforded a convenient means of fastening the forms without having to run bolts or wires all through the concrete.

The reservoir, when finished, showed some white streaks formed by the freezing of the water, which leaked from the reservoir while it was under its initial test. There were practically no leaks except at the construction joints or horizontal planes between the successive pourings of the concrete. The total leakage when the reservoir was first tested was not much over 3,000 gallons per twenty-four hours. The contractor at first unwisely tried to stop the leaks by washing the inside of the reservoir, first with Sylvester mixture and then with cement. These coatings failed to adhere, and were of no value in stopping the leaks. No cracks of any sort could be detected in the reservoir even with the aid of a magnifying glass. The horizontal planes between successive pourings of concrete were plainly visible, and it was recommended that these be dug out in V-shaped grooves, running all around the reservoir, and having a depth of about 1½ in. and a width of 1 in. at the surface, and that these grooves be carefully filled with a mixture of ironite and cement. This was done and the leakage was effectually stopped.

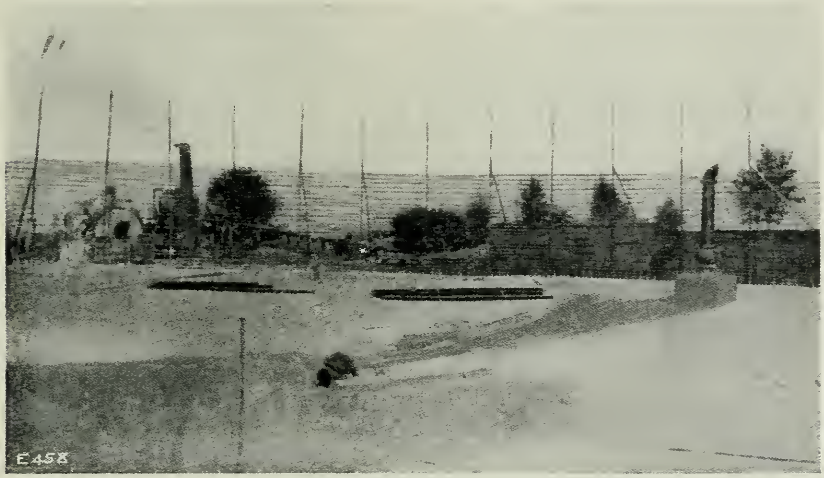


Fig. 6. 2,000,000-gallon Reservoir during construction.

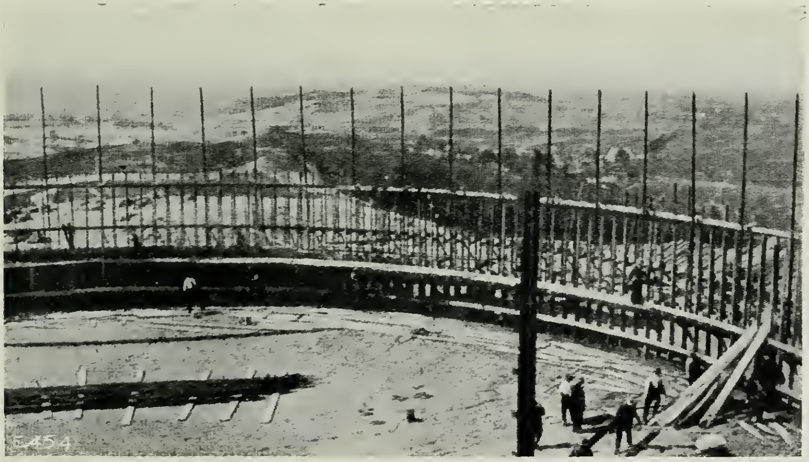


Fig. 7. Erection Forms and Steelwork, 4,000,000-gallon Reservoir.
WATERWORKS RESERVOIRS.

The construction of the 4,000,000-gallon reservoir, the wall of which was shown in *Fig.* 3, developed some surprising results. The enlargement to the old reservoir already shown in *Fig.* 2 was built by the same contractor who built the new reservoir shown in *Fig.* 3, the two jobs being parts of the same contract. The new reservoir was built first and the enlargement to the old reservoir was made after the new reservoir had been put in service.

In this case, as in all the others mentioned in this paper, the contractor was required to guarantee the watertightness of the finished work.

After the award of contract the writer discussed with the contractor the methods which he planned to employ in building the reservoir, and was informed that he intended to erect an elevator tower between the two reservoirs, construct the forms for the whole 32 ft. in height of wall, and place his concrete in the wall by means of chutes, working day and night, and pouring the concrete continuously until the entire wall was poured. The writer objected strongly to this method of construction, and endeavoured to persuade him to abandon it and to use removable forms not more

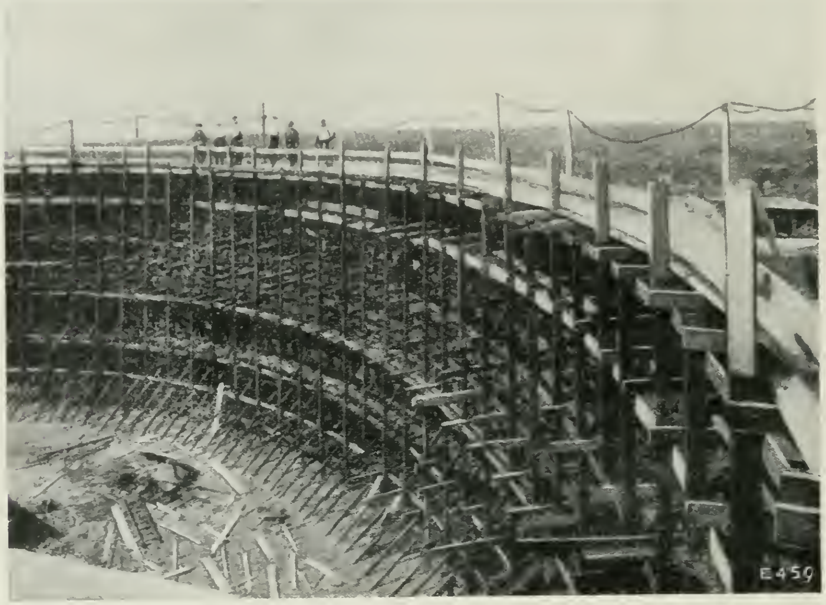


Fig. 8. View of 4,000,000-gallon Reservoir after placing of Reinforcing Steel in the Wall.

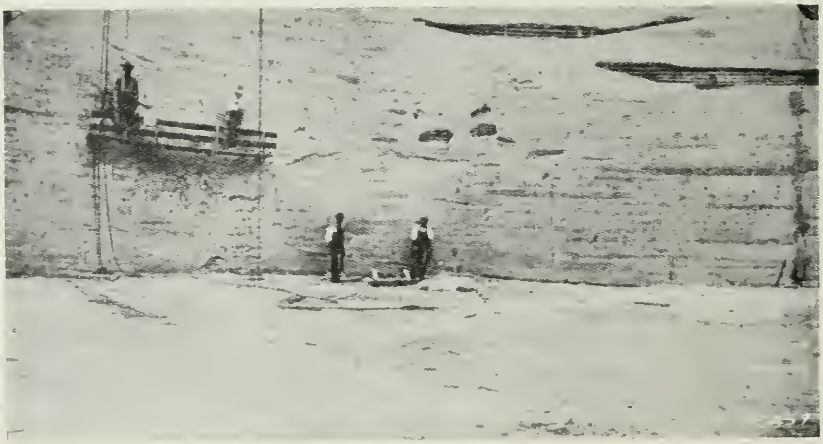


Fig. 9. Cutting Out Soft Spots and Patching in 4,000,000-gallon Reservoir.

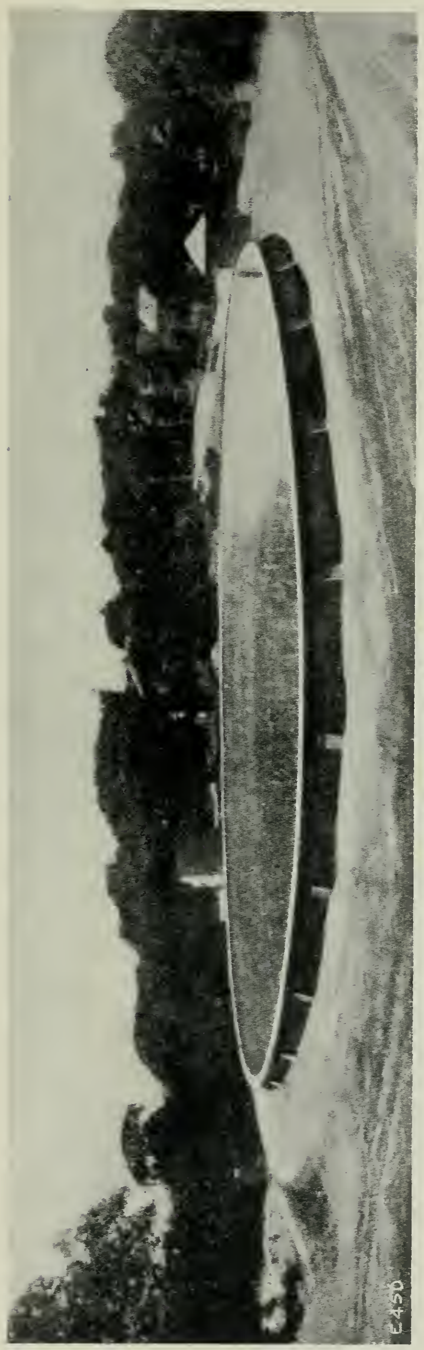


Fig. 10. 7,500,000-gallon Reservoir Complete, except for Grading, Turfing and Fencing.

WATERWORKS RESERVOIRS.

than 2 or 3 ft. in height, so that the concrete could be thoroughly spaded in place in the wall. Sketches of such forms were prepared and estimates secured on steel forms, which seemed to prove that they would be much cheaper than the wooden forms contemplated by the contractor. The contractor, however, argued that he had in stock a lot of lumber which could be used for forms and which he could so manipulate that it would suffer very little damage from such use. He further stated that he was afraid that leaks would occur in the joints between successive pourings. Finding himself unable to persuade or to compel the contractor to change his method of construction, the writer was obliged to allow the work to proceed.

In the meantime the contractor asked permission to use a cement with which the manufacturers mixed at the mill a certain alleged waterproofing material. This cement, so mixed, was subjected to the usual laboratory tests by one of the city engineers who had charge of the supervision of the construction work on the ground, and passed successfully all of the tests applied, complying with all of the requirements of the standard specifications of the Society for Testing Materials. Permission was accordingly granted to use this brand of cement, subject always to the provisions of the contractor's guarantee of the final results.

Fig. 7 shows the erection of the channels, forms, and reinforcing steel for the wall in progress.

Fig. 8 shows the appearance of the structure after the reinforcing steel had all been placed in the wall, and the scaffolding for the wall forms had been practically completed.

Construction work proceeded rapidly, and it was evident that the contractor was doing all that could be expected of him to secure good results, but when the forms were removed the entire surface of the wall was seen to be spotted with patches of a creamy or yellowish colour. Investigation showed that wherever these patches occurred the material could be readily dug out of the wall with a penknife, and this material contained no sand or stone, was almost as porous as a sponge or a piece of coral, and was so light that a lump of it would float in water. It was then evident that the so-called waterproofing mixture was of a soapy nature, and that when the concrete was poured down the chutes to its place in the wall this soap formed a lather which separated from the stone and sand and from most of the cement, and lay on top of the rest of the ingredients. Just enough of cement appeared to remain in this lather to cause it to take a set.

Fig. 9 shows the inside of the wall after the forms were removed, with some of the contractor's men cutting out the soft material and endeavouring to replace it with real concrete.

There were hundreds of these soft spots, most of which extended entirely through the wall, the largest being about 25 ft. long by 3 or 4 ft. deep. The contractor did his best to dig them all out and put good concrete in place of them; but, as might be expected, the reservoir still leaked after this had been done. When all of the soft spots had been dug out, and before the holes had been refilled with concrete, the structure resembled a gigantic bird cage as much as it did a reservoir..

It was finally necessary to put in a membrane lining of waterproofing material over the wall and bottom, and to cover this with a protecting coat of several inches of reinforced concrete. This produced a watertight reservoir.

In the construction of the enlargement to the old reservoir, it is needless to say that the contractor did not pour all of the wall at one pouring, and that he did not use the so-called waterproofing substance. When the forms were removed from the second piece of work there were a very few small leaks, which either stopped themselves in a short time, or were stopped without much difficulty.

Regarding the construction of the 10,000,000-gallon reservoir, the wall of which was shown in *Fig.* 4, and notwithstanding the fact that the price which the contractor for this reservoir received yielded him no profit whatever on the job, he spared no expense to make his work first-class in every particular, and he succeeded in this respect better perhaps than the contractors for any of the other reservoirs herein described.

After the forms were removed from the wall the space between the embankment and its outer surface was filled with water to test the wall for leakage. The inner surface of this wall was 942 ft. long by 15 ft. high, and in this entire area there were but three spots which showed any dampness. From one of these there was a small trickle amounting to only a few drops per minute.

There were no spots on the entire inner surface where stone showed against the forms, and this result was largely due to a device for which the contractor should be given credit. In building the wall a portable plate of thin metal was held at all times about $\frac{3}{4}$ in. away from the inner form, and as each batch of concrete was poured behind this plate, one-to-one cement mortar was poured in front of the plate and between it and the inside form, in quantities sufficient to keep the upper surface of the mortar level with the upper surface of the last batch of concrete. These plates were moved ahead as the pouring progressed around the circumference, being from time to time drawn up so that the mortar in front of them could unite thoroughly with the concrete behind them before either had time to begin to set.

Fig. 10 is a view of the completed reservoir and gate house, taken before the grading had been finished and before the ornamental fence designed to protect the reservoir against pollution had been erected.

When this reservoir was finished and tested by filling the space between the outside of its wall and the surrounding earth with water, a number of spots showed on the inside, and there were two or three small streams which spurted out from the inner surface of the wall. When the reservoir was filled and the loss of water measured with a gauge, it was found that this amounted to about 32,000 gallons in twenty-four hours, of which a very small part was due to evaporation. The wall of this reservoir was poured in 4-ft. layers, and steel dams 8 in. high and $\frac{1}{8}$ in. thick were provided at each construction joint for the purpose of minimising the tendency to leakage at these joints. Incidentally, these dams, which were bolted to the vertical channels, assisted materially in the erection of the channels. There was only one leak of any size at a construction joint, and at this spot the surface of the joint had been covered by a fall of clay from the bank above, and the contractor had evidently failed to remove all of this clay.

The specifications for this reservoir, as well as those for other more recent ones, called for the use of a vacuum cleaner for cleaning the surface of the concrete already poured before fresh concrete should be poured on top of it. The work was not, however, supervised by the writer, and this provision was not carried out, the contractor simply brushing the joints in the usual manner before pouring the next batch of concrete. This brushing of the joints cannot give the best results, for the reason that the dust and rubbish and laitance are simply moved from one part of the surface to another, whereas if a vacuum cleaner were used they could be removed entirely.

Fig. 11 is a construction photograph of a 1,200,000-gallon covered reservoir.

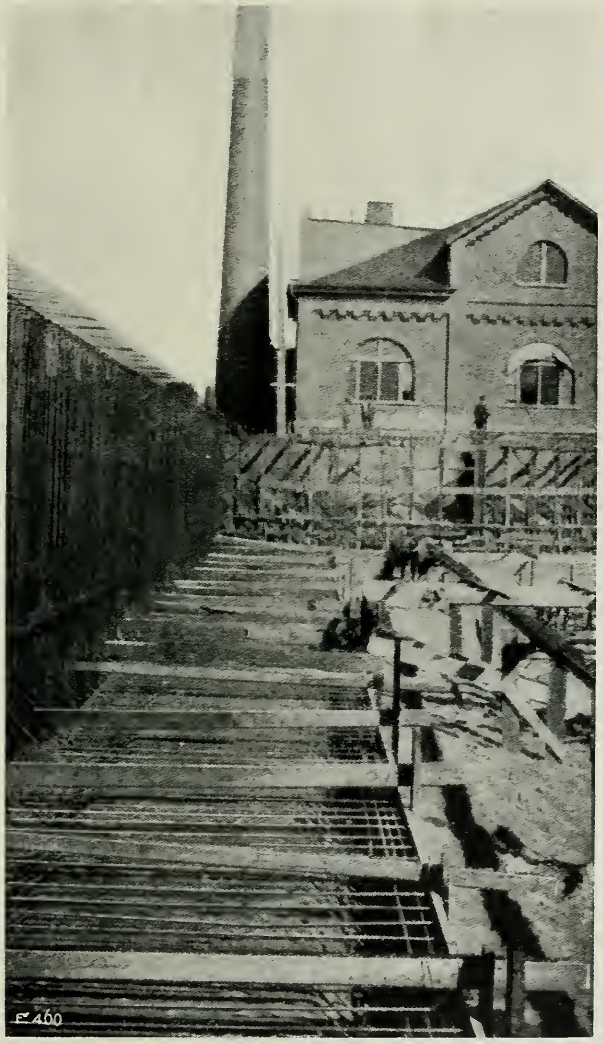


Fig. 11. Construction View of Covered Reservoir.
WATERWORKS RESERVOIRS.

Attention is called to the unusually careful and accurate manner in which the contractor for this work placed his reinforcing steel, the correct alignment of which shows very plainly in the photograph. This contractor also devised and used with great success a steel frame or templet for building the groined arches. These frames were so light that they could readily be moved from place to place, and the foundations for each column, instead of being built in four pieces, as is usually the case in this type of construction, were built in one piece, the concrete being simply piled up and tamped inside of the frame and smoothed off with a screen which was passed along the upper surface of the corner angles of the frame. The groins were then given a trowel finish.

The workmanship on this reservoir was unusually good, the only defects being a few rough spots, which were promptly corrected by the contractor.

CONCLUSIONS.

As a result of his experience with these and with a number of other concrete reservoirs, the writer would draw the following conclusions :—

1. It is entirely possible with proper materials, mixture, and workmanship to prevent moisture from passing through a concrete wall a foot thick even under fairly heavy pressures.

2. It is not to be expected, however, that the perfection of workmanship required to produce these results will always be obtained at every single point over an area of thousands of square feet of wall.

3. Such leaks as may show in spite of conscientious efforts to do good work can almost invariably be stopped entirely or be reduced to such a point that they will stop themselves in the course of time, especially if the water carries iron or sediment.

4. Leaks are most likely to occur at construction joints. The use of steel dams will reduce the danger of such leaks, but these dams cannot always be relied upon to prevent the leakage, and their presence should not be allowed to diminish in any way the precautions which should always be taken to prevent leakage at the joints.

5. The surface of concrete which has begun to set should be scratched and roughened, and all dust, rubbish, and laitance should be carefully removed with a vacuum cleaner before the next batch of concrete is poured. This will not always prevent leakage, but it will go far towards doing so.

6. In reservoir construction the use of chutes for conveying concrete to its place in the wall should not be permitted unless the concrete is thoroughly remixed just before it reaches its final place in the wall.

7. While good results can be obtained by very careful spading of the concrete adjacent to the forms, so as to keep the stone away from the inner surface of the wall, it is believed that far better results would be secured by the plan devised by the contractor for the 10,000,000-gallon reservoir already described—namely, the use of a portable sheet of thin metal with means for holding it about $\frac{3}{4}$ in. away from the inner form, the concrete to be poured back of this sheet of metal, and cement mortar in front of it and between it and the form.

NEW WORKS IN CONCRETE

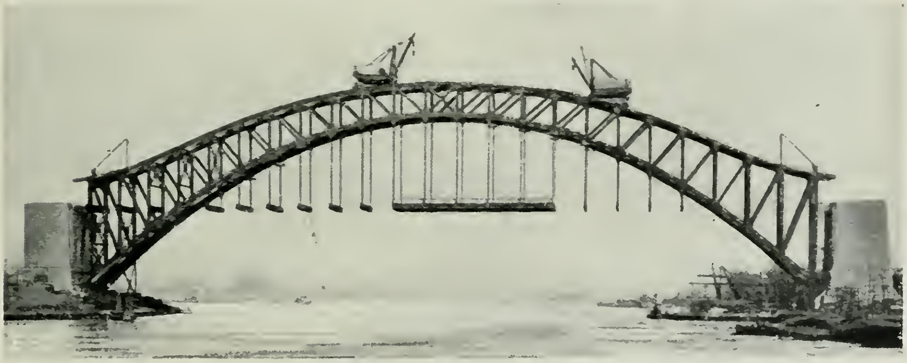
AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

THE NEW YORK CONNECTING RAILROAD.—THE HELL GATE ARCH BRIDGE AND OTHER STRUCTURES.

One of the most important features in connection with the New York Connecting Railroad is the large Hell Gate Arch Bridge, which spans the East River at Hell Gate between Ward's Island and Astoria, Long Island.. It ranks amongst the world's greatest bridges as the longest steel arch, and as a structure of unusual proportions.

It was designed and built by Gustav Lindenthal, chief engineer of the New York Connecting Railroad, at a cost, including approaches, of $25,000,000. The span of the arch is 1,016 ft. 10 in. between tower faces. The upper chord of the arch is 300 ft. above mean high water at the centre and 180 ft. at the ends of the span; the lower chord is 260 ft. above mean high water at the centre and 40 ft. at the ends; the roadway is 140 ft. above mean high water.



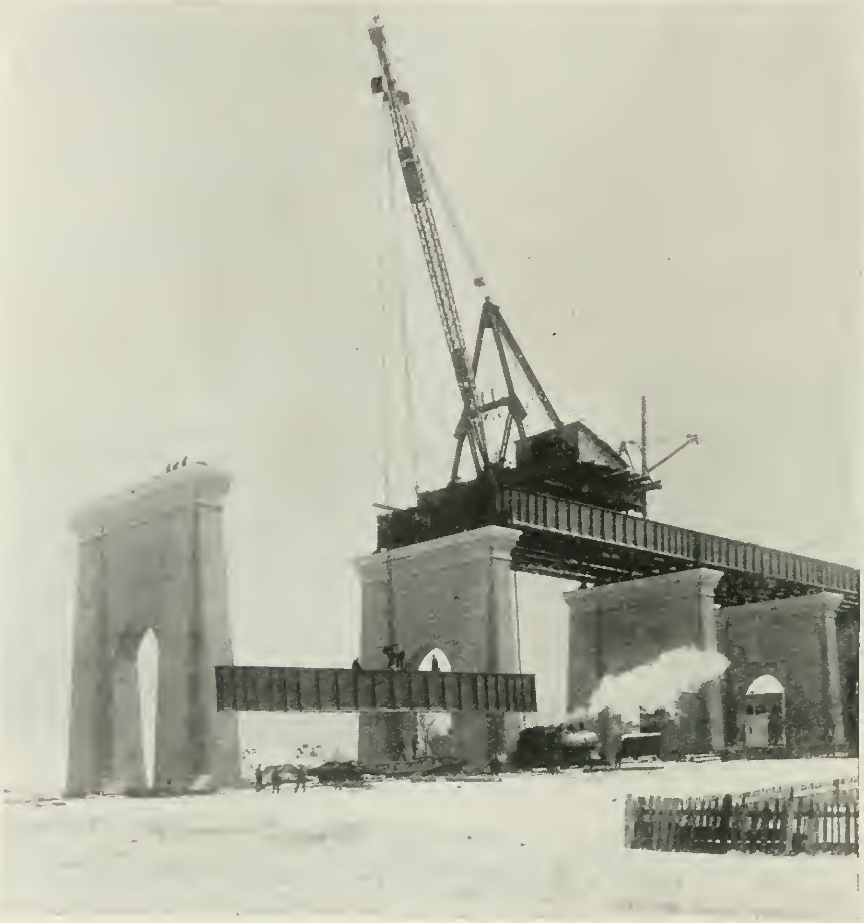
Hell Gate Arch Bridge.
New York Connecting Railroad.

The arch carries four railway tracks (two passenger and two freight) on a solid concrete deck. It is the heaviest bridge in the world, weighing 52,000 lb. per lineal ft., and carrying a loading of 24,000 lb. per lineal ft., making a total carrying capacity of 76,000 lb. per lineal ft. The steelwork weights 19,000 tons, and the flooring and track weigh 7,000 tons. The heaviest single member weighs 185 tons, and has a cross-section of 1,384 sq. in.

The width of the bridge is 93 ft. between railings, and 60 ft. between centres of trusses.

The Long Island tower is 104 by 140 ft. at the base, and is founded on rock in open cut at 20 ft. depth. The Ward's Island tower is 119 by 140 ft. at the base, and rests on twenty-one pneumatic concrete caissons, founded on rock varying from 58 to 120 ft. below the ground surface. Height of towers, 240 ft. Total concrete used in the towers is 110,000 cubic yards. The total concrete in the bridge towers and approaches is 500,000 cubic yards.

The construction of the arch was commenced in November, 1914. The arch was erected by cantilevering out from the towers, each half being held by connection to temporary backstays built behind the towers. The two halves were joined on October 1, 1915. The entire steelwork was completed in January, 1916, and the bridge will be opened to traffic about January, 1917.



Concrete Piers for Viaducts, Hell Gate Bridge.
New York Connecting Railroad.

Eastern Viaduct.—The Eastern Viaduct is a structure 3,480 ft. long, and consists of an embankment between vertical retaining walls, interrupted at the intervening streets by reinforced concrete arches and steel bridges. The walls are 3 ft. thick at the top, with a face batter of 1 in 40. They are tied together through the earth-fill, giving a form of construction similar to the reinforced concrete U-abutments frequently used by some railroads. As just stated, the viaduct is pierced by a number of concrete subways spanning the entire width of the street with simple concrete arches, which are on a skew and semi-circular in section, excepting in the case of Debevoise Avenue and Hemler Street, where the arches are flat. The viaduct structure, including arches, is built as a monolithic, with no expansion joints, there being sufficient steel in the side walls to provide for temperature changes.

Ward's Island Viaduct.—Our frontispiece shows a photographic illustration of this viaduct, which adjoins the Hell Gate Arch, and is half a mile long and 135 ft. high. It is characterised by a sweeping curve of three degrees and ten minutes in its approach and contact with the Hell Gate Bridge. As will be seen from the photograph, the viaduct is supported by concrete piers.

View showing a part of the Eastern Viaduct with Concrete Street Arch.
Hell Gate Bridge.

MEMORANDUM.

Reinforced Concrete Piles in the Foundation of a Bridge.—A bridge has recently been constructed in the neighbourhood of Nizza, Monferrato, carrying the road to the railway station across the River Belbo, a mountain stream which is almost dry during the greater portion of the year, but rises in certain seasons very rapidly to a great height. The bed at Nizza consists of a very fine clayey sand. An older stone arched bridge had been destroyed by floods, and the piers, which still stood, had been utilised to carry an iron girder bridge of 35 metres span, which had, however, proved inadequate to carry the traffic. It was, therefore, decided to replace it by a reinforced concrete bridge of three spans, with two intermediate piers. In order to obtain a satisfactory foundation it was necessary to descend to a depth of 15 metres below the river, at which depth firm clay was found. According to *Il Cemento* (March, 1916), it was finally decided to employ pentagonal reinforced concrete piles on the Zublin system, the engineers being Messrs. Ghelfi and Cordoni, of Milan. These piles are reinforced with five round bars at the angles, each being 18 mm. diameter, the radius of the inscribed circle being 19 cm., and the transverse reinforcement being twisted bars along the periphery and diameters. The area of concrete in the section of each pile was thus 1,295 cm^2., and that of the steel 13 cm^2. Twelve piles were used for each pier, the load per pile being 40 tons, and the piles were driven at an angle in order to give a better distribution of the load.

A special inclined steam pile driver was used. About 1,600 blows were usually necessary. The heads of the piles were quite intact after this treatment.

The abutments had next to be strengthened by means of reinforced concrete beams. These were 6 metres long, 16 cm. deep, and 56 cm. wide, each being reinforced by means of eight longitudinal 12-mm. rods and transverse 8-mm. rods at the periphery at intervals of about 20 cm; these were prepared in the factory. The beams were provided with interlocking joints. They were built into the old abutments to provide a firm foundation for the new bridge.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Elementary Strength of Materials. By Ewart S. Andrews, B.Sc.

London: Chapman & Hall, Ltd. 216 pp.+viii. Price 4/6 net.

Contents.—Strain, Stress, and Elasticity—The Behaviour of Various Materials under Test—Repetition of Stresses; Working Stresses—Riveted Joints; Thin Pipes—Bending Moments and Shearing Forces on Beams—Geometrical Properties of Sections—Stresses on Beams—Deflection of Beams—Columns, Stanchions, and Struts—Torsion and Twisting of Shafts—Springs—The Testing of Materials.

This book is practically an abridged edition of the author's larger book on the same subject, and it has been prepared for those readers who do not require to go in for an advanced course of study in engineering and building. The text is presented in a simple manner, and the student is gradually led from an explanation of the fundamental principles to the various formulæ required for practical work. A very useful chapter is that devoted to the behaviour of materials under test, and a careful study of this section will enable the reader to realise and appreciate the characteristics of the materials which he will be using. Two excellent chapters are also devoted to the actual testing of materials, with illustrations of the various machines used.

Before dealing with the relation between the bending moment and the stresses in a beam the author wisely introduces a chapter on the geometrical properties of sections, and thus the way is properly prepared for the student. There are many good diagrams throughout the book, and some useful exercises and tables are given at the end. The volume may be described as one which contains a very good combination of theoretical and practical matter, well arranged and expressed, and it should prove extremely useful to all students in engineering and building.

Building Code. Recommended by The National Board of Fire Underwriters, New York. 326 pp.

This is described as an ordinance providing for fire limits, and regulations governing the construction, alteration, equipment, repair, or removal of buildings or structures. Every possible requirement seems to have been covered for the three classes into which buildings have been arranged according to the type of construction adopted. These classes are: (1) Frame construction; (2) Non-fireproof construction divided into sub-sections—(*a*) ordinary construction, (*b*) mill construction; (3) Fireproof construction. The term "frame construction" as here used indicates a building having the exterior walls or portions thereof of wood, a type which is happily non-existent in this country as far as new permanent structures are concerned. The non-fireproof construction applies to all buildings having exterior masonry walls and floors and other interior construction wholly or in part of wood; while buildings of masonry, steel, or reinforced concrete construction, in accordance with certain specified requirements, are considered fireproof. Although the regulations are comprehensive, and such as to guarantee sound construction and satisfactory design, a certain amount of latitude within reasonable limits appears to be permissible, and in some respects the conditions are not so stringent as those obtaining in this country. As an example, the section providing for resistance to wind pressure only specifies an allowance of 20 lb. per square foot of exposed surface, instead of the amount of 30 lb. usually adopted here. This is a sensible requirement, and we have repeatedly advocated a modification of the laws in force in this country, which call for unnecessary wind resistance.

Several illustrations are provided to make the requirements perfectly clear, and the text is well arranged and indexed in a manner which makes reference easy to any particular section. The book reflects great credit on the committee responsible for its compilation and publication.

The Architects' and Builders' Pocket Book. By the late Frank E. Kidder, C.E.

London: Chapman & Hall, Ltd. 1816 pp. + xxiii. Price 21/- net.

This present volume is the sixteenth edition of a useful handbook for architects, structural engineers, builders, and draughtsmen, and it has been revised by Mr. Thomas Nolan, who was assisted by a staff of specialists. The original arrangement adopted by Mr. Kidder has been adhered to, by which the book is divided into three parts—Part I. dealing with the practical applications of arithmetic, geometry, and trigonometry; Part II. with the materials of construction and the strength and stability of structures; and Part III. with miscellaneous useful information for architects and builders. It has required three years of hard work on the part of Mr. Nolan and his staff to prepare the book for publication, and the amount of material contained therein is such that it fully justifies the time expended. It is impossible to give even a brief *résumé* of the contents, as these appear to cover every conceivable requirement of the architect and builder. The portion devoted to notes on reinforced concrete covers nearly 90 pages, and in this a great deal of useful information is given. Many of the notes dealing with various systems and materials are necessarily more useful to the American reader than to those in this country, as those responsible for the preparation of the book are resident in America; but, apart from this, the amount of generally useful information is sufficient to make it a valuable book to all those connected with structural work, and it deserves to find a place in every architect's and builder's office.

The Construction of the Panama Canal. By William L. Sibert and John F. Stevens.

London: D. Appleton & Co. 339 pp. + x. Price 7/6 net.

Contents.—Introduction—Sea Level versus Lock Type of Canal—The Reconstruction of the Panama Railroad—Prosecution of the Work—Development of Working Plans—The Housing and Feeding of the Force—The Assemblage and Management of the Force — The Adopted Project — Changes in the Adopted Project—Changes in Dimensions of Parts of Canal—Designs for Permanent Buildings and Locks—Construction from Colon to Gatun—Excavation and Concrete Work at Gatun—Construction of Gatun Dam—Gatun Lake—Construction from Gatun to Pedro Miguel—Culebra Cut—South End of Culebra Cut to the Pacific Ocean—Municipal Engineering—Shops and Terminal Facilities—Operation of Panama Canal—The Work and Its Cost.

The construction of the Panama Canal is one of the most wonderful engineering feats ever accomplished, and the description of the work and general organisation as presented in this book makes very interesting reading, not only to those engaged in engineering, but also to the general public. For the purpose of description the scheme is divided into two sections, the first of which is given as the preparatory period, covering the operations from 1904 to March, 1907, and the second dealing with the construction period, extending from March, 1907, to April, 1914. Mr. John F. Stevens, who wrote the chapters describing the preparatory work, was the chief engineer during this period, while Brigadier-General Sibert, who is the author of the text on the construction period, was in charge of the building of the Gatun Locks and Dam and of all the work on the Atlantic division. The whole of the book is, therefore, written by those who are best qualified to describe the details and operations, and as the subject is presented without the use of very technical language no skilled knowledge is necessary to the reader.

The whole of the primary considerations in the designing of the canal, together with the views of various parties as to the merits of sea level and lock type, are given at some length, and, in fact, the only criticism we would make as to the way in which the book is written is that there is a tendency to reiterate the same points to such an extent as to make the reader a little wearisome. The magnitude of the scheme can hardly be realised, and the work accomplished appears more wonderful when all the details and difficulties to be overcome are explained. A particularly interesting section is that dealing with the construction at Gatun. There are more than two million cubic yards of concrete in the Gatun Locks alone, and in order to complete these locks within the contemplated time it was necessary practically to double the world's record for placing concrete, which at that time was about 1,700 cubic yards per day. There are many such items given in the volume, which is illustrated by some excellent photographs and maps, and the reader can get a very clear idea of the actual work executed. The fact that the undertaking was completed within the estimate both as to time and money reflects great credit on those responsible for the general organisation and supervision. The book should appeal to all classes of readers as one which deals with a world-famous achievement in a simple manner, and its educational value should be great as indicating what can be accomplished by the skilful application of modern appliances.

MEMORANDUM.

Concrete Shaft Equipment.—In an article in the *Journal of the Chemical, Metallurgical, and Mining Society of South Africa* Messrs. W. W. Laurie and G. Hildick Smith give an account of the concrete shaft equipment in the central shaft of the Bantjes Consolidated Mines. The equipment consists of concrete shaft rail foundations as continuous stringers through the shaft, these stringers being a substitute for timber sills in inclined shafts. The rails are laid and held in position on the stringers by holding-down bolts. With regard to the employment of concrete for this purpose the authors arrive at the following conclusions:—

Provided always that there is no danger of movement of the footwall of a shaft, concrete stringers as shaft rail foundations are preferable to timber sills in incline shafts, with any angle of dip up to 45 degs., for the following reasons:—

(1) A longer life can be obtained from the rails, which can be allowed to wear down with safety to a greater extent on a continuous concrete foundation than they can when laid across timber sills.

(2) Skip derailments do much less damage with concrete than with timber.

(3) Concrete is a much more permanent foundation than timber, requires no repairs or renewals, and appears to suffer no damage from any cause whatever.

(4) In deep shafts considerable time is saved during the equipment of the shaft, there being no long timbers to handle.

(5) If more than one pair of skips is to be used in a shaft, the shaft may be equipped for two skips only until such time as other hoisting capacity is required, thus saving the extra cost of equipment at the moment.

(6) Less damage to rails from corrosion by acid water.

With regard to the maximum inclination at which concrete stringers can be used in incline shafts, it is thought that by pegging the footwall at inclinations from 45 degs. up to 60 degs. concrete stringers could be safely held in position.

ENQUIRY.

We shall be pleased to receive any replies from our readers as to their experience on the point raised in the following letter.—ED.

GENTLEMEN,—This Association has received at various times inquiries from tanners in various parts of the United States on the serviceableness of concrete in tannery construction.

There appears to be very little information on the effect of tannin liquors on concrete. At least there have been but few investigations in this country on the subject, and these investigations are of such a character that they cannot be pointed to with assurance that the results obtained are final. We are at the present time conducting an investigation on the effect of tannin liquors at various stages on concrete surfaces and we wish to solicit your co-operation in this matter.

Perhaps it will be apropos to explain our position in the matter. We are maintained by the various cement companies in the United States and Canada for the purpose of promoting the use of cement and the dissemination of knowledge concerning its proper use in permanent construction.

A few years ago we had Dr. A. S. Cushman, Director of the Institute of Industrial Research, conduct some experiments on this subject. He constructed a small number of concrete tanks, in which he placed the tannin liquors and noted the action at various stages. The following is a summary of his tests :—

The Effect of Tannin Solutions on Portland Cement Concrete.

> At the end of practically one year the tanks containing tannin solutions are practically unaffected, with the exception of one specially treated tank, in which the lining of neat cement containing 15 per cent. of concrete oil sloughed off to some extent. During these tests, for the first three months some slight action upon the concrete was caused by the tannin solution, but this action was very slight and soon ceased, the tanks having in fact become tanned. This first action of the tannin liquors upon the cement, though slight, is of such a nature as to produce dark colouration upon leather tanned in new tanks. For this reason we recommend that a new concrete tank be well tanned with the liquor before leather goods are introduced. After each refilling a sludge deposited in the bottom of the tanks, but similar deposit also formed in the glass containers. Both are due to a settlement of heavy organic matter. *It is safe to state at the present time that plain Portland cement concrete is suitable for the storage of tannin solution.*

Do you know where and how successfully concrete has been used for the storing of these liquors, or has there ever been conducted any tests or investigations on the subject? If so, will you kindly advise us where and how we can obtain the results of these investigations?

Thanking you for your co-operation in this matter, and assuring you that we will greatly appreciate any help which you may give us, we are,

Very truly yours,

TECHNICAL DIVISION,
Portland Cement Association, Chicago.

To CONCRETE AND CONSTRUCTIONAL ENGINEERING.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Iron and Steel Institute (Autumn Meeting).—The autumn meeting of the Institute will be held, by kind permission, at the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, 21st and 22nd September, commencing 10.30 a.m. on the 21st and 10 a.m. on the 22nd. Amongst the papers to be read and discussed are the following:—"The Influence of Elements on the Properties of Steel," by Dr. J. E. Stead, F.R.S.; "Some Properties of Ingots," by Mr. H. Brearley; "Steel Ingot Defects," by Mr. J. N. Kilby; etc., etc.

Engineering Standards Committee.—At a special meeting of the Main Committee (Sir John Wolfe Barry, K.C.B., Chairman), held on July 27th last, Mr. Charles le Maistre, A.M.Inst.C.E., M.Inst.E.E., who has been in charge of the work of the Electrical Section since 1903, was appointed Secretary to the Committee in succession to the late Leslie S. Robertson, M.Inst.C.E., who was lost with Lord Kitchener in the disaster to H.M.S. *Hampshire* whilst on an important Government mission.

Technical Institutions: The City and Guilds of London Institute.—The Session 1916-17 is announced to commence early in October; all applications for the registration of classes in technology must be received at the offices of the department not later than October 7th. The complete syllabus for structural engineering will be found in the programme for the session, and examinations are announced to take place early in May. Full details can be had on application to the Institute, Department of Technology, Exhibition Road, London, S.W.

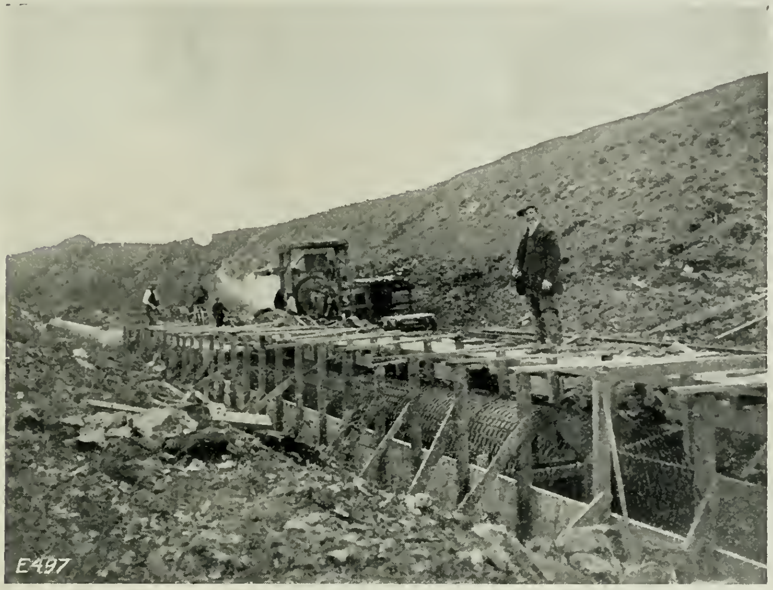
University of Manchester (Faculty of Technology).—The prospectus for the Session 1916-17 can now be obtained on application to the Principal. The syllabus of classes covers every branch of engineering work and other technical subjects, and attention is also given to advanced study and research. Intending students should apply to the Principal for full details as to times of classes, particulars as to examinations, etc.

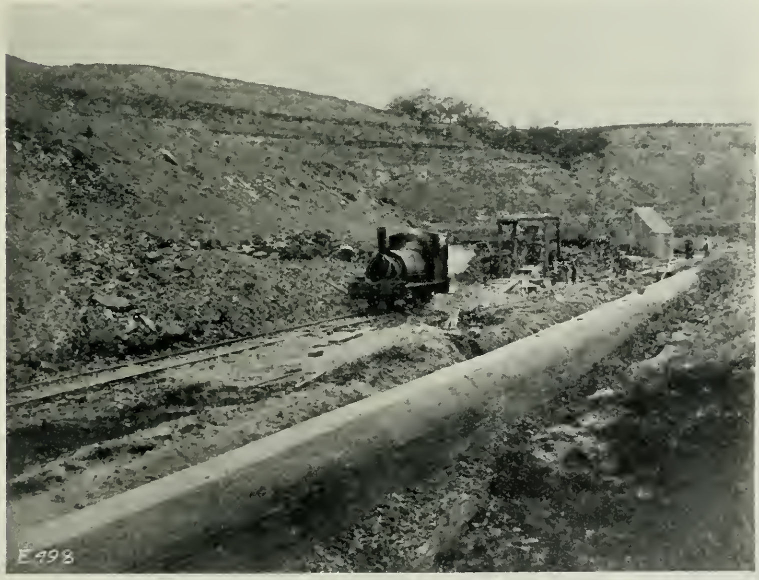
Luton Railway Bridge.—This bridge has recently been completed for the Great Northern Railway, and is of interest as representing the first passenger line bridge renewal carried out in this country up to the present date in reinforced concrete. The new bridge comprises two girder skew spans, each 43 ft. between abutments by 14 ft. 9 in. wide, the total width being 29 ft. 6 in. The two spans meet along the centre line and are structurally separated. The test load consisted of an Atlantic type Great Northern locomotive weighing 110 tons.

Bridge near the Conway.—A steel bridge on concrete and masonry foundations, laid on piles, has been erected over the Conway near Dolgarrog. The centre span, formed of steel girders, is 140 ft. in length and 14 ft. 6 in. above the flood level of the river. There are two approaches in steel work, each 130 ft. long, also supported on concrete foundations. The new bridge, which carries a duplicate line of 15-in. pipes, will ensure the water supply to Colwyn Bay and Glan Conway being regularly maintained.

Expanded Steel Concrete Culvert.—Below we give two illustrations of culvert constructed at Parson Byers Quarry, Stanhope, for Messrs. Bell Bros., Ltd., Middlesbrough, under the supervision of their engineer, Mr. Mark Halliday. The culvert is

3 ft., inside diameter, and 900 ft. long, and is reinforced throughout with 3 in. diamond mesh expanded steel. The object of the culvert is to continue an old water course and to allow of an adjacent tip for refuse being extended. The design and reinforcement for the culvert were supplied by the Expanded Metal Co., Ltd., of London and West Hartlepool.





The Cost of Cottage Construction.—The question of cheap cottages is being widely discussed again at the present moment. We have repeatedly dwelt upon the

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possibilities of concrete in this connection, and it may be interesting here to give an abstract from an article which has appeared in *Municipal Engineering and the Sanitary Record* under the title, "Can the Cost of Cottage Construction be Reduced?":—

Various Forms of Construction Described.—The various forms of light construction are familiar—timber, corrugated iron, concrete, and even steel. The two first-named may be dismissed as unsuitable. The last-named is more or less at an experimental stage. There remains concrete as a last alternative, and its possibilities rather than its present attainments deserve the application of the best brains available. There are several varieties of concrete construction—solid or hollow concrete blocks, solid concrete walling, monolithic concrete walling, and reinforced solid walls. There are possibilities about all these, but serious objection is taken to solid walling on the score of dampness. If that cannot be eradicated the solid wall is out of court, as weatherproof is a first principle. Probably the hollow wall will best repay investigation. It makes for dryness and warmth, and there should be a future in such a wall constructed, say, 7 in. in thickness, consisting of rough cast 3½-in. wall, 1½ in. hollow space, and lath and plaster. It looks as if the present operations up and down the land for the housing of munition workers will contribute towards the elucidation of concrete building. Already buildings of this nature have been erected, and more are to follow, as they combine the essentials of cheapness and rapidity in construction. Rapidity in construction is of course a primary consideration at the moment, but after the war it will be almost equally so, as the disbanding of the armies will provoke an immediate and insistent demand for houses. Various contractors have recently offered to erect 250 cottages in a period of four months, which is certainly at least twice as rapid as brick construction. In point of stability the light concrete cottage cannot yet compare with the brick one,* and this is one of the lines along which improvement must be sought. Brick houses have a life usually estimated at sixty years, as against a maximum of thirty for the concrete. That, however, does not put concrete out of the running. If it can be made to remain perfectly weatherproof for thirty years it will tide the country over the critical period following in the wake of peace.

The supreme recommendation of concrete is its cost. As already stated, the brick or stone house at current cost of construction involves a rental beyond the means of the working man, and is calculated to remain so. The usual type of house consisting of living-room, scullery, bath-room, and three bedrooms costs at present over £300, exclusive of roads, sewers, and other services. If the money is borrowed at 4½ per cent. and the loan spread over a period of sixty years the economic rental works out at approximately 10s. per week. The light concrete house of the same accommodation, but with water-closet instead of bath-room and rather less cubic space, can be built for £170. If a loan is obtained at 4½ per cent. for thirty years the economic rental is about 6s. per week, which is a rent that can fairly be expected from the working man.

A Systematic Campaign Suggested.—The situation demands that some systematic campaign should be organised, and there is no better channel than the various technical institutions. Every endeavour should be made to attract the best brains, and every encouragement shown to practical suggestions. Experts might be appointed to visit the localities where light construction can be inspected in its various forms. Numerous buildings of this character have now been erected sufficiently long to enable an accurate estimate to be made of their capacity to withstand climatic conditions. The results of these investigations might then be communicated to meetings of the institution and discussions originated, with a view to improvement in such matters as stability, design, convenience, and cost. The need is great and time is short.

A Hinged Concrete Bridge.—A bridge of 30 m. span being required to connect factories on opposite sides of a branch railway near to the Alessandria-Genoa line, it was decided to construct a single span arch of plain concrete. On account of the considerable tensile stresses, however, it was resolved to provide hinges at the abutments and crown. The thickness of the concrete is 0·50 m. at the crown and 1·20 m. at the abutments. Each hinge is composed of a bundle of steel rods, arranged fan-wise, those at the abutments consisting of five rods each and those at the crown of four. The fans are 14 cm. apart. Thin iron plates are inserted during the setting in place of the concrete to preserve the necessary opening for the action of the hinge. The behaviour of the arch on removing the centering was quite satisfactory, and the bridge has now been for some time in regular use. The cost was 120 lire per square metre of platform surface.—*Il Cemento.*

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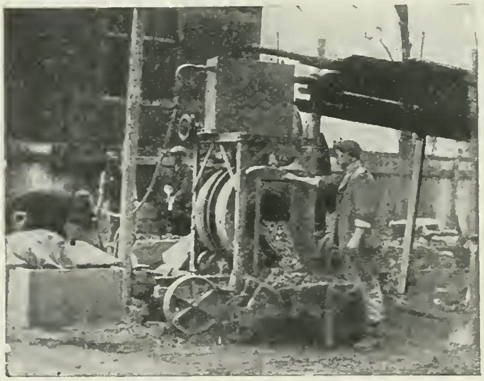
* See our Editorial comment on this, page 461.

A Graphical Method of Computing Reinforced Concrete Structures.—The third, fourth, and fifth issues of *Il Cemento* for 1916 contain an account by Luigi Figari of the Italian method of computing reinforced concrete structures by means of charts. It is claimed that this method, commonly attributed to German engineers, is really of Italian origin, the names of General Caveglia, Lieut.-Colonel G. Figari, and the engineer Galizia being specially mentioned. The charts are very simple in form, all the lines being straight, but their construction is somewhat complicated, the formulæ employed being of the logarithmic type. The simplicity of the charts is then secured by the use of logarithmically-ruled paper. The details do not lend themselves to a summary.

TRADE NOTE.

The Hydraulic Mining Cartridge.—The hydraulic mining cartridge, a machine for breaking rock, concrete, etc., has been used at many electrical generating stations and in many docks and harbours during the last few years, and has recently been used in connection with an important Government contract for alterations to dock walls in a North of England seaport. The work involves the disintegration of about 30,000 cu. yds. of concrete, which was laid down about twenty years ago The walls are, approximately, 10 ft. above water level and 30 ft. below, and a series of holes have been drilled about 6 ft. apart and 38 to 40 ft. deep. The upper sections, averaging about 10 ft. in thickness, are first removed to a depth of 15 to 20 ft.; below this depth divers are employed to insert the machine in the hole, pressure being applied from the pump at the surface. The power required to break the concrete varies according to the conditions of each operation, but is usually about 150 to 200 tons, representing a pressure of 6 or 8 tons per square inch. The breaking up of the walls by explosives is impossible in this instance, as not only is it desired to avoid explosive shots because of their effect on valuable plant and war vessels in the vicinity, but because portions of the walls below water level must be secured from damage and shock of every kind. Besides the machine used in these important operations, hydraulic cartridges have recently been sent out to South Africa for similar work at Algoa Bay.



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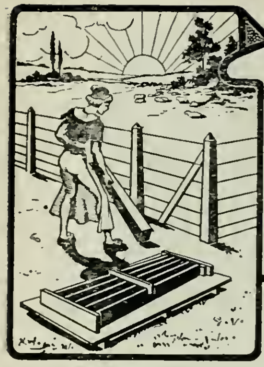
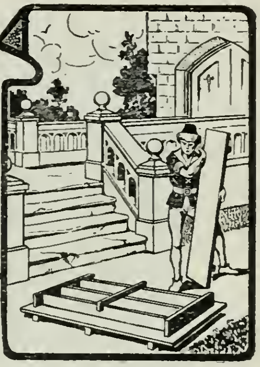


CONCRETE THE MONEY SAVER



ORNAMENTAL CONCRETE PRODUCTS.

(continued.)

(Continued from August issue.)

Fig. 12 shows a seat made entirely of concrete and manufactured by the students of the School of Industrial Art of Pennsylvania, U.S.A., and is a fine example of the suitability of concrete for outside ornamental work. It also tends to prove that it does not want a thoroughly experienced man to do this class of work.

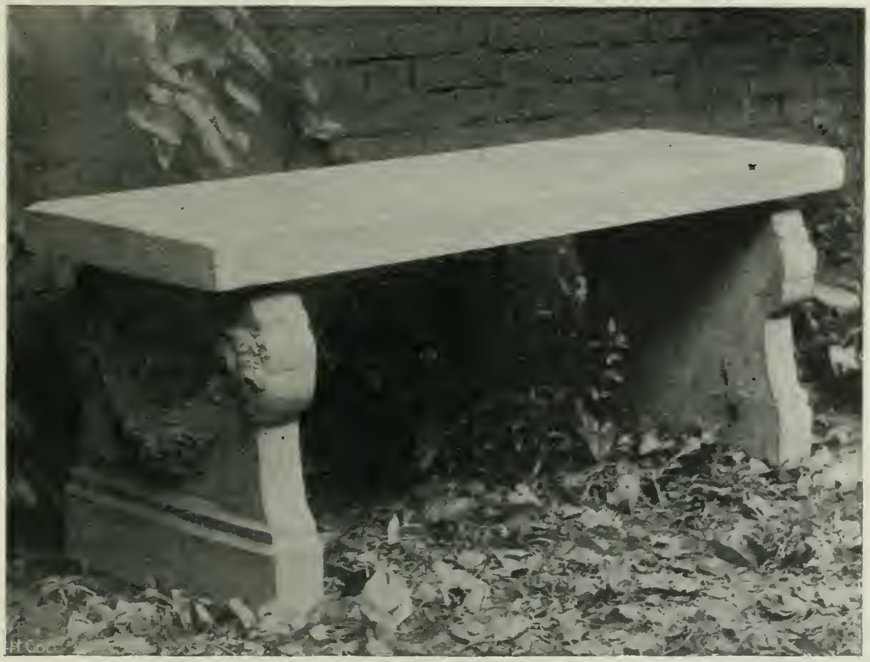


Fig. 12. Concrete Garden Seat.

In *Fig.* 13 a combination of artistic concrete goods is shown. It is a fountain of about 15 ft. diameter. The walls and bed were made *in situ* of reinforced concrete, in which expanded metal was used.

The central pillar supports a concrete basin which carries the brass fountain. The basin is surrounded by a balustrade. The base, copings, and balustrade were made in Liverpool, and were carted to the site, which was Caergwrle Spa, North Wales. The whole of the work was carried out by Mr. J. S. Rigby, F.C.S., of Liverpool, and has given entire satisfaction.

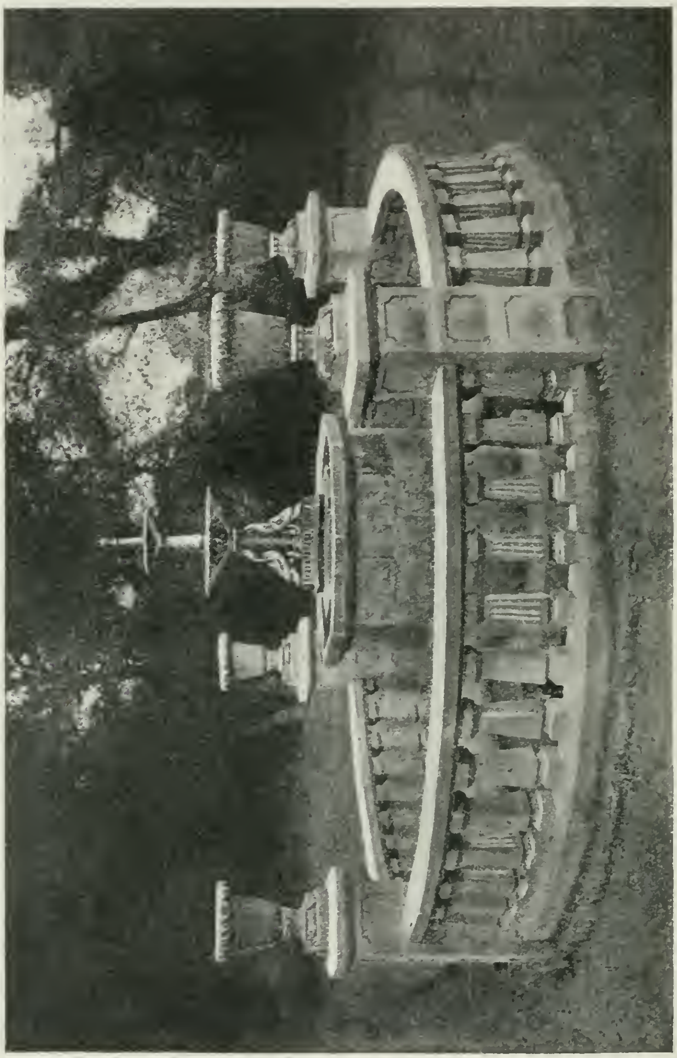
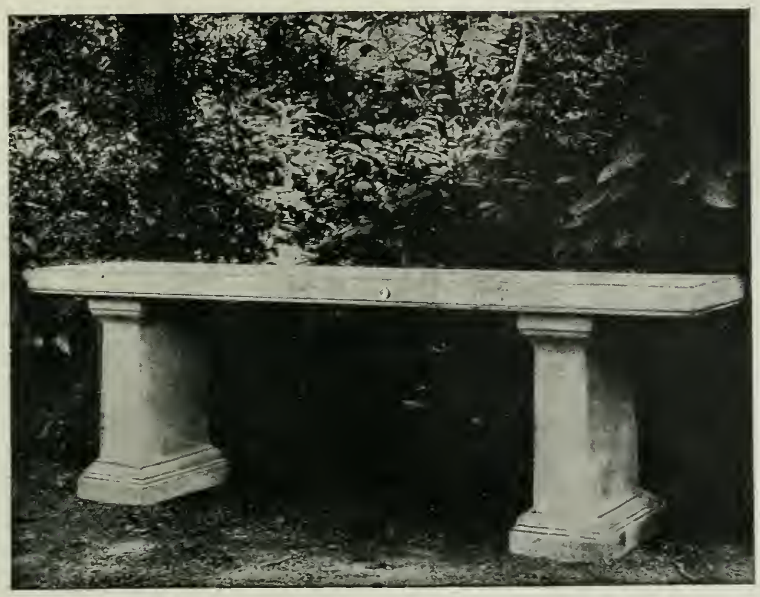
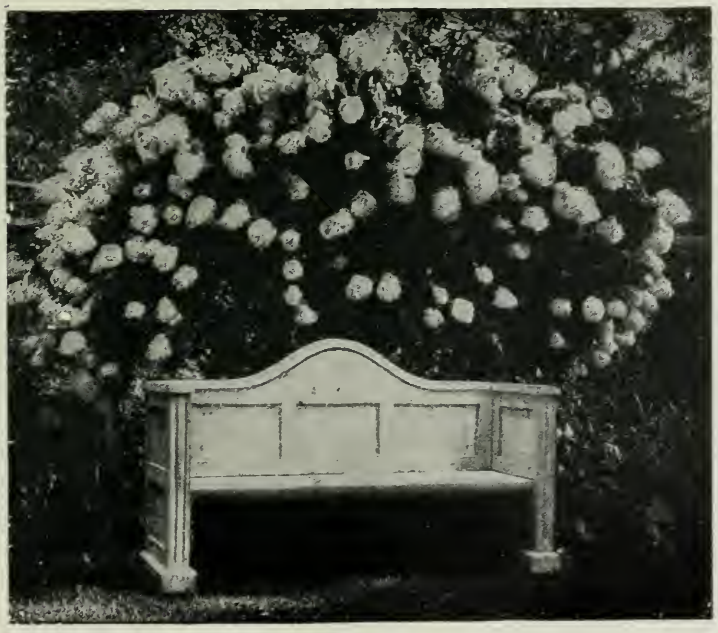


Fig. 13. Reinforced Concrete Fountain in North Wales.

Figs. 14 and 15 are also examples of concrete seats, which show the general utility of concrete.





Figs. 14 & 15 Concrete Garden Seats

Another type of seat which is manufactured in this country is composed of two concrete chairs or ends, which are held together with strips of oak which form the seat and back of the seat. There is one drawback to this, and that is when the oak is out in the rain there is a certain amount of stain from the oak, and if the oak strips are fixed to the concrete ends by iron bolts or coach bolts the stain will be more pronounced, as the action of the oak upon the iron causes the iron to rust,

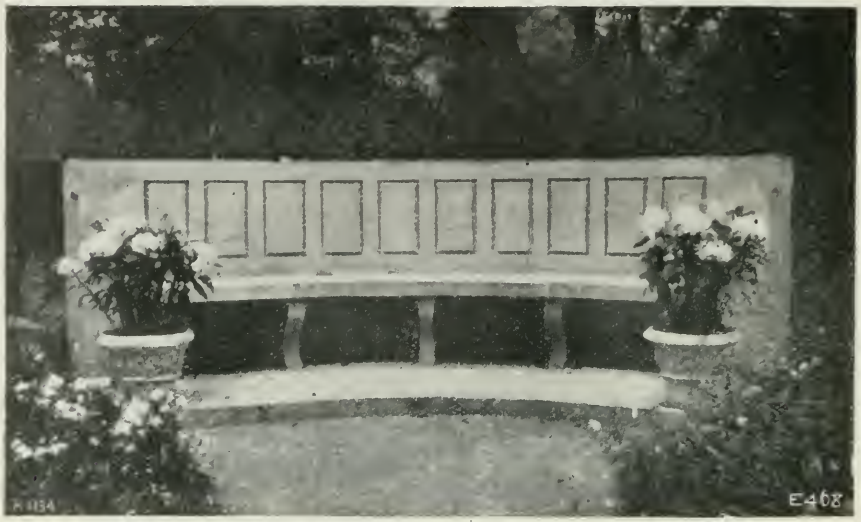


Fig. 16. Replica of Seat in the Vatican Grounds.

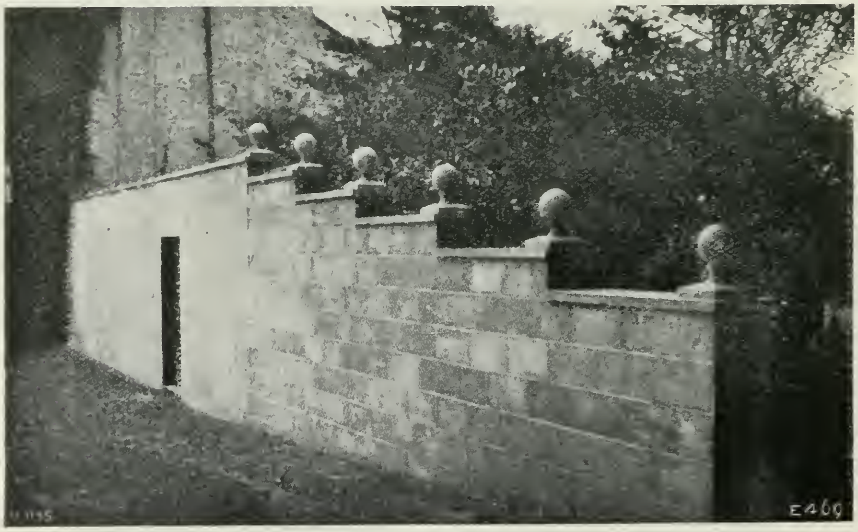


Fig. 17. View of Garden Wall at La Mancha Hall, Southport.

and when the rain beats on the seat the rust water runs down the concrete and a stain is instantly made. To obviate this, the bolts should be galvanised. All the seats, vases, balustrade, etc., are made in moulds as described before, and are faced up with various fine aggregates, such as sharp sand, crushed granite, and the like.

Fig. 16 shows another form of seat, and, as will be seen, it is in circular form. *Fig.* 17 is a view of a garden wall on the same estate. This wall is constructed with concrete blocks which are faced on both sides, and the thickness of same is 14 in. *Fig.* 18 shows the same wall, but on the other side. The balls and copings are all made in concrete, and the whole of these works were constructed by Mr. Rigby, of Liverpool, and the same can be seen at La Mancha Hall, near Liverpool

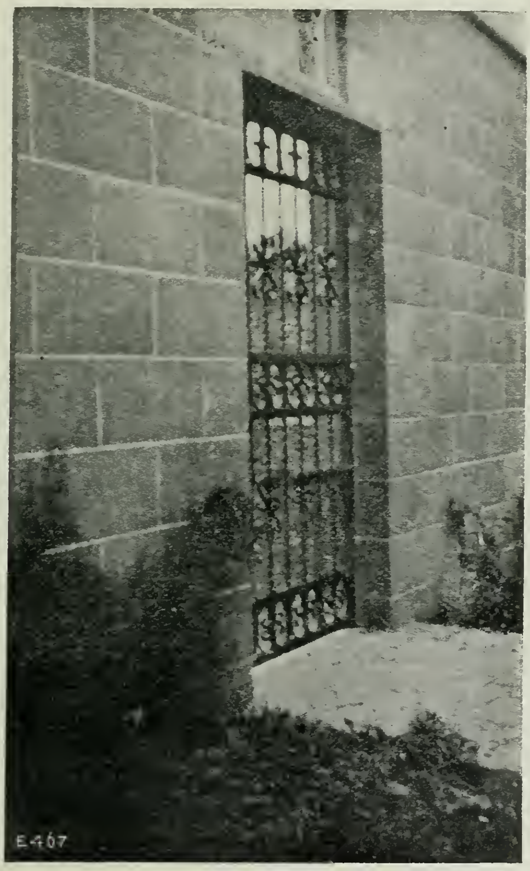
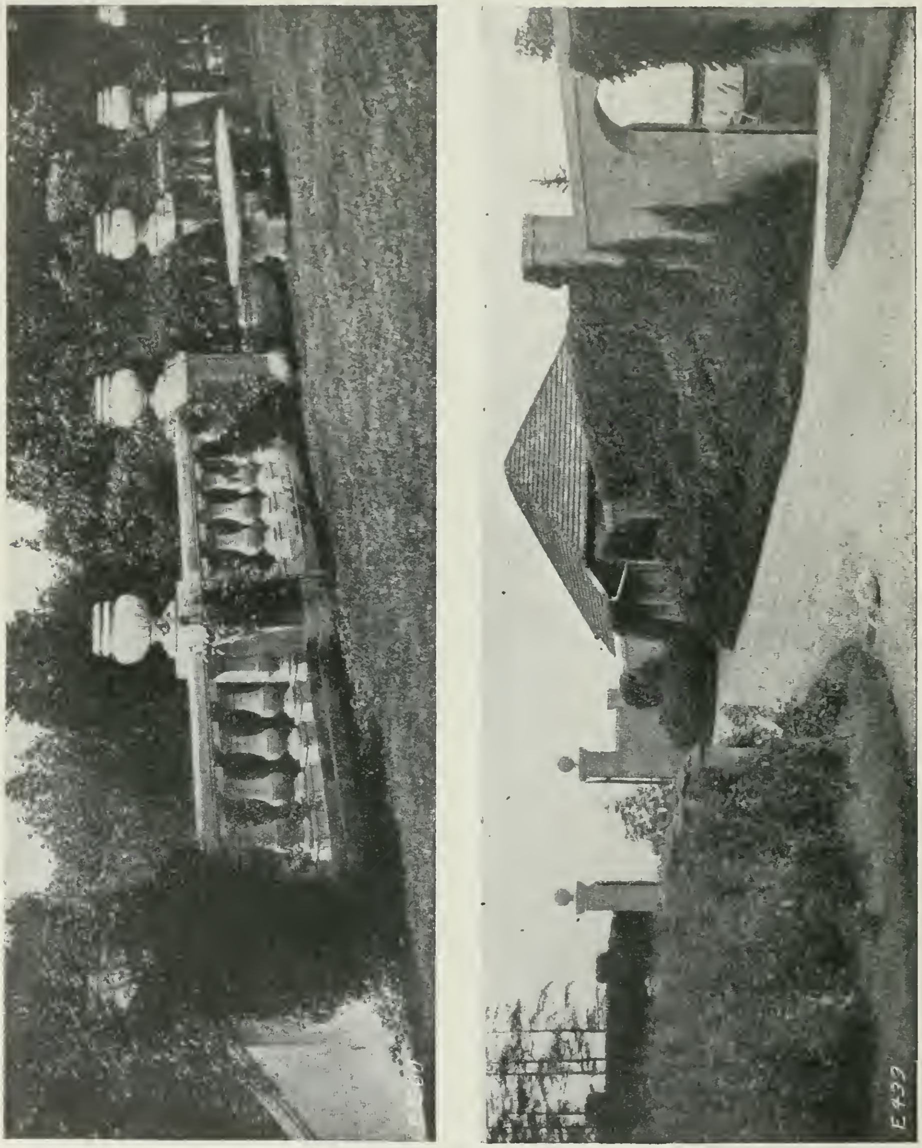


Fig. 18. View of Garden Wall at La Mancha Hall, Southport.

Figs. 20, 22, and 23 are views of entrances to parks, gardens, etc. These were carried out on the monolithic principle, as this form lends itself best to a monolithic type of architecture, as, for instance, of wall space unbroken by joints, and this form is capable of being adapted to the various requirements needed in garden construction. Different effects can be easily obtained by varying the sizes of the aggregates, and also by adopting different finishings to the surfaces. The illustration, as shown in *Fig.* 19, is a very fine example of concrete work upon a garden terrace, and these examples show how readily and easily any adaptation of concrete is applicable to property in this country for any work of ornamentation in parks and gardens.



Figs. 19 & 20. Examples of Concrete Garden Work.

Fig. 21 shows the use to which concrete has been put for garden frames and conservatories. The whole of the work as shown in *Figs.* 19 to 23 inclusive were carried out on estates in the United States.

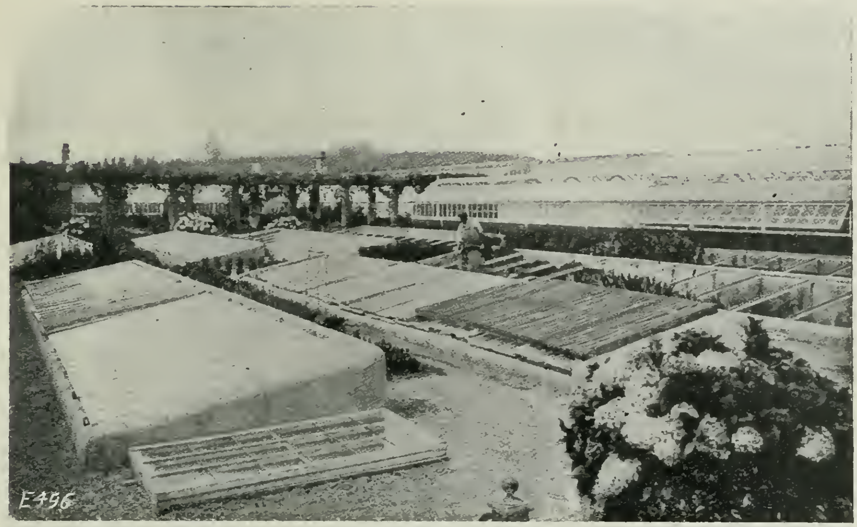


Fig. 21. Showing Use of Concrete for Garden Frames and Conservatories.

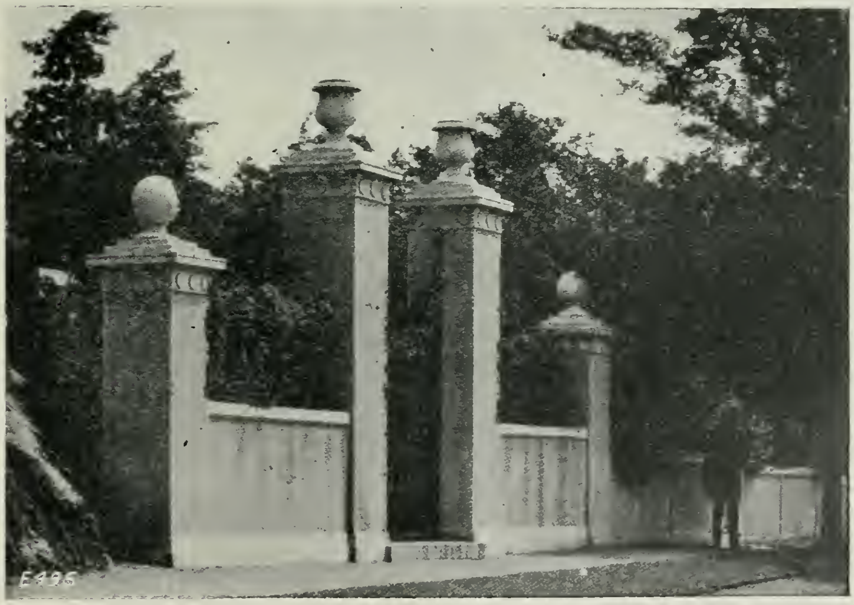


Fig. 22. Example of Concrete Garden Work.

The illustrations shown and described in this article do not include all the ornamental work which can be made in concrete, and such articles as flower-boxes, sundials, pergolas, and practically any ornament for the garden can be made of this material, and even tables have been made with success. The most favourite aggregate for this type of work is marble or stone, because of their lasting qualities, and as years go by so they gain in strength. Another feature which is of great importance is that owing to the density of the marble or stone (if the articles are made in a proper manner) they will require no protection against the severest of weather; freezing and thawing will not have any effect on their strength and rigidity. The G.E. Railway are now using small concrete blocks, with the top edge rounded off, for the edging to flower beds, etc., on their stations, and coloured concrete garden edging is being used extensively in some parts, and very ornamental articles are made with it. At Puy, in France, a monumental statue has been made of concrete. The total height of it is over 70 ft., and it was cast in separate pieces, and jointed together *in situ*, and held by a reinforced concrete framework. The statue looks like one block of stone, as the joints are not perceivable.

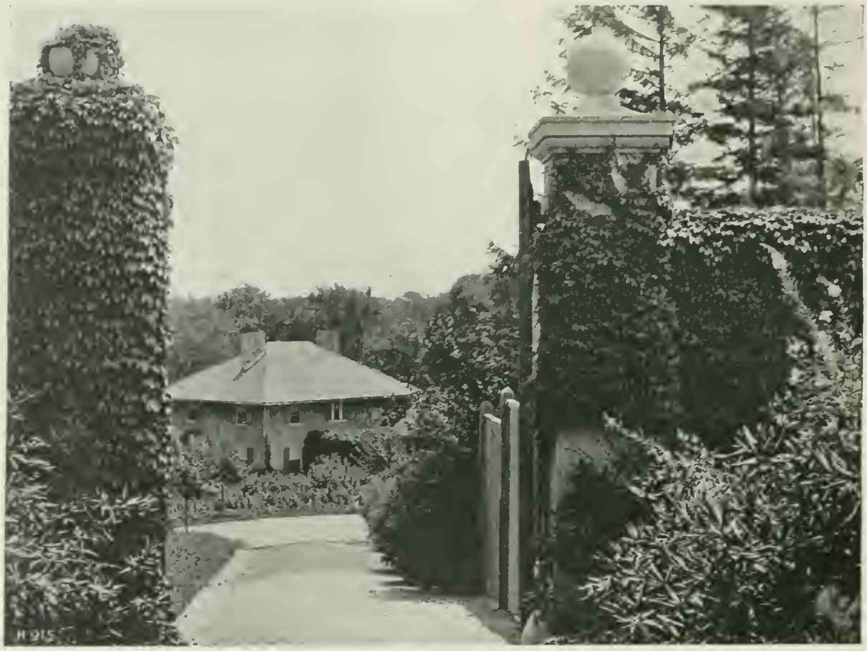
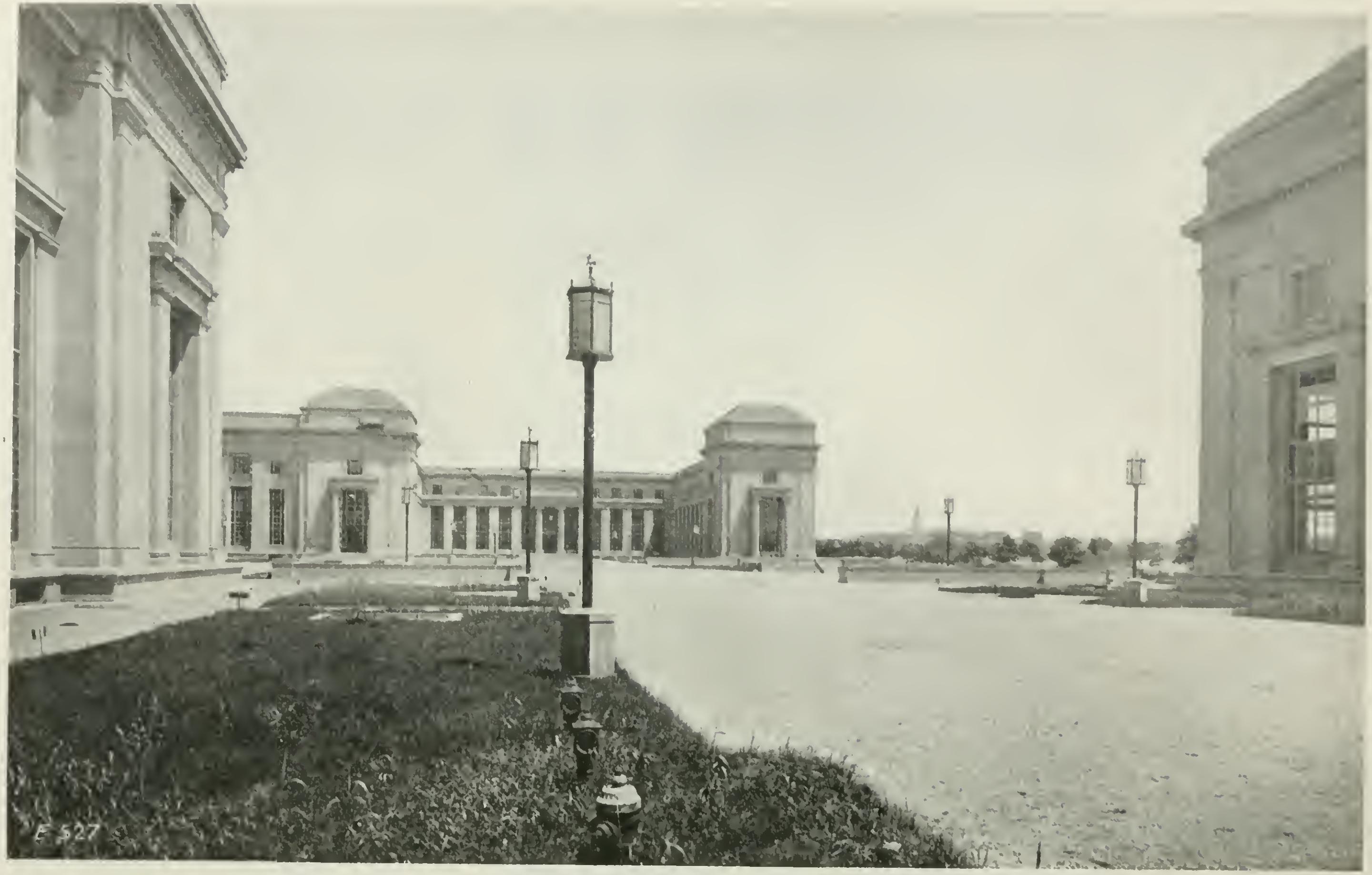


FIG. 23. CONCRETE GARDEN WORK.

NOTE.—The following subjects have been dealt with :—"Concrete Fence Posts," "The Adaptability of Local Materials and their Application for General Purposes," and "Ornamental Concrete Products."

In our next issue we propose starting a series of articles on "Concrete Block Making."



View Looking East across Minor Fore Courts.
The New Buildings, Massachusetts Institute of Technology.
(See page 521.)

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XI. No. 10. LONDON, OCTOBER, 1916.

EDITORIAL NOTES.

STANDARDISATION AND ENGINEERING.

A PAPER was recently read before the British Association by the Secretary of the Engineering Standards Committee which dealt with "Standardisation and its Assistance to the Engineering Industries," and in this some interesting facts were given. The author dealt in the first instance with some general views, which showed the necessity of standardisation and the benefits which accrue to both producers and users.

It is now generally accepted that a certain amount of standardisation is necessary for economic production; but the range of products to which the principle has been applied is capable of considerable extension, and it is to be hoped that good progress will be made in the near future. There are some who do not entirely agree with standardisation, because it stifles individuality and originality, and tends to produce too much of the stereotype practice. The author of the paper realises this fact, however, and he states that those responsible for the initiation of the standardisation movement in Great Britain realised from the first that it would be necessary, from time to time, to revise standards, and this has become recognised as an essential part of any standardisation work, which never can be regarded as final. This is a very important point, because progress and improvement in any process or product must be encouraged, and, as necessary, existing standards must be altered to include such improvement, and the whole community will benefit by uniformity of good practice. It will be found that the recognised standard article and work is of good quality, and generally can be taken as a safe guide by those who wish to cover all the essentials of good practice, and for this reason the existence of a standard type has the effect of raising the quality of work produced, while it ensures fair competition among manufacturers and prevents the conscientious merchant suffering through doubtful practice on the part of a rival. There is a great satisfaction in preparing an estimate for standardised work, because the estimator knows that competitors are being compelled to price on the same basis of good materials and workmanship. The paper passes from the general views on the subject to the inception and growth of the Engineering Standards Committee, which was founded in 1901 through the initiative of Sir John Wolfe Barry, K.C.B.

It must be remembered that the British standard specifications have no authority other than that of public opinion, and thus their wide adoption, as shown by the Secretary in his paper, is remarkable, and speaks well for the co-operation of all the members and the excellence of the publications. In drawing up industrial standards experimental investigations frequently become necessary, and these are carried out by the National Physical Laboratory, which acts as the official testing bureau of the Standards Committee.

Nothing is, therefore, neglected to make the standards as perfect as possible, and the Committee thoroughly deserve all the success they have attained. The standard specifications have been adopted for various materials and articles by the Admiralty, Board of Trade, Lloyd's Register, Indian Government, and Home Office, amongst other bodies, and this should be sufficient evidence that standardisation in engineering practice is desirable and generally acceptable when properly organised and carried out.

It is interesting to note that the British Standard Specification for Portland cement is now generally adopted by engineers and manufacturers throughout the whole country, and the large number of copies of the specification which have been sold—3,500 copies since the 1910 revision—goes to show its general utility to the industry. For 1913 the output of Portland cement of the country was over 3,000,000 tons, 95 per cent. of which, it is estimated, was made to the British standard.

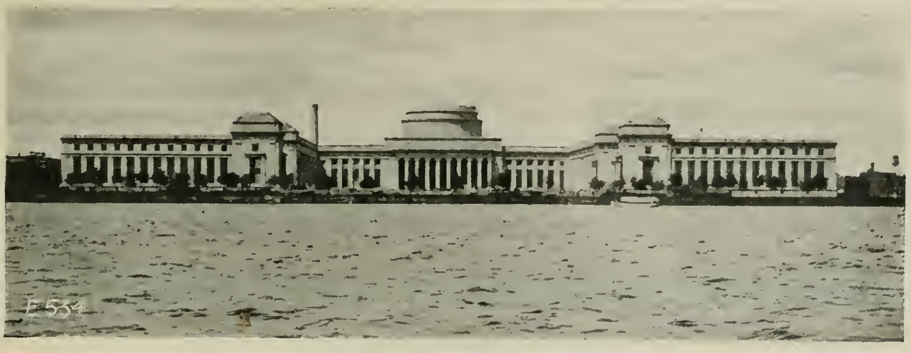
This is a typical case, where the benefits of standardisation can be seen. The engineer's labours are reduced to the minimum in his specification, as he will merely state that the cement is to conform to the requirements of the British Standard Specification, and at the same time a sound material will be guaranteed. The manufacturer who supplies the cement knows intimately the standard required as it is the one to which he works in the production of the material, and there is no question of irksome conditions and varying requirements which necessitate constant readjustment in manufacture, and consequent increase in cost.

Engineers have become so familiar with standard beams, angles, and similar sections that they would be inclined to say it would be impossible to do without standardisation in this respect, and yet the same principle would apply to any other factors in engineering, and once recognised standards had been set up, we should never be content to go back to the confusion which is inevitable when no standard prevails.

Again, there is the question of interchangeability, which is extremely important in many branches of engineering, and it is here that standardisation is absolutely essential.

It must be remembered that there are many cases of what may be termed "unwritten standardisation," that is to say, in ordinary practice methods and materials become, to a certain extent, universal among engineers, and although no publication is issued which gives them the stamp of official standard types, they are nevertheless recognised as such, and adopted by all engineers of good repute.

Standardisation should be developed to its fullest extent, as it prevents waste, confusion, and unfair competition, while it promotes good work, speed, and economy, and in the trade struggle which is inevitable in the near future good standard types will greatly assist us in maintaining our position in the engineering industry.



View into Court from middle of River.

NEW BUILDINGS FOR THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

In our issue of April, 1915 (page 159), we gave a short illustrated account of this building in course of construction, and we are now able to present some further particulars of the completed structure, which is an excellent architectural example of the application of reinforced concrete. The particulars and some of the illustrations we publish by courtesy of the "Architectural Review" from an article by Mr. H. E. Kebbon, Resident Architect, whilst other illustrations have been placed at our disposal by the Stone Webster Engineering Co., of Massachusetts.—ED.

THE new Technology buildings are now completed, and were inspected and dedicated in June of this year.

The architectural scheme for these new buildings differs in two important essentials from the usual method of housing educational institutions. These two differences are basic, and the reasons that have caused their adoption are of interest.

First, instead of arranging the buildings about one axial line passing through the centre of the site, two axes were established, both at right angles to the river front (*Fig.* 1). Upon the axis dividing the western half of the property it was decided to erect the main Technology buildings, and upon the eastern axis the residential buildings are to be grouped, including the Commons, Walker Memorial, Club House, Gymnasium, and Athletic Field.

The second radical departure from the usual has been the adoption of one enormous structure, to provide space for all the different departments under a continuous roof, instead of dividing them into separate buildings.

To take up first the division of the land—the scheme of dividing it into two distinct units was adopted as a matter of common-sense convenience. The general proportions of the property do not favour a group of buildings around a central courtyard and extending along the entire frontage of the property. The importance of the river frontage forced its recognition as the principal façade, and it was obvious that the study buildings should adjoin Massachusetts Avenue, the main thoroughfare, by which the buildings would be approached from the residential sections of Boston and Cambridge. Locating this main group of buildings on the western half of the site made it also possible to obtain the view into the courtyard when approaching the site across the Harvard Bridge.

From an architectural standpoint it became clear that the most effective treatment was a system of courts, with the principal court opening towards the water, thus giving a southern exposure; the whole dominated by a dome rising above a colonnaded portico at the northern end, which serves to tie the group together and to emphasise the character of the whole.

Opening out from this Main Court to the east and west are two small lateral courts, which will have a certain atmosphere of seclusion. All these courts will be paved, with grass plots framing the paved areas, and with trees and shrubbery to add colour and interest to the ensemble. Stone balustrades and seats also will tie the various units together.

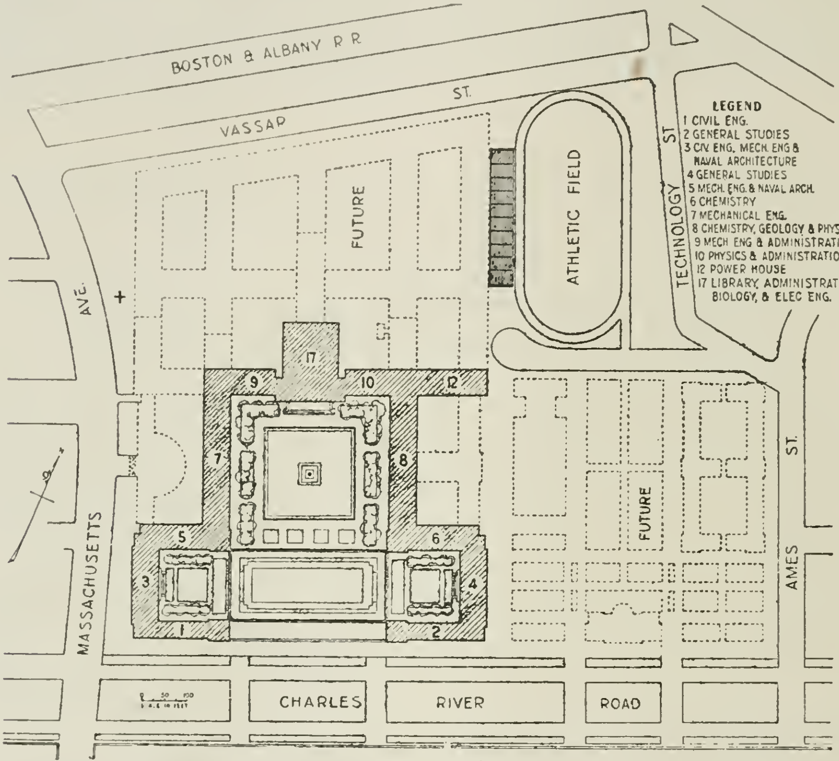


Fig. 1. Site Plan.

New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

After consideration there was no doubt that a single building to house all the class-rooms, offices, and laboratories of the various departments was the most practical solution. The departments are so used that students are continually passing from one to another, and combining them in one building was an obvious convenience and saving of time.

Sufficient space at the rear of the portion of the study group now completed is available for future expansion equal to twice the present needs of the

Institute, and this future construction has been planned for in designing the present buildings.

Although the new Technology is housed under one roof, yet the plans allow for a logical division of the buildings into different groups. The general plan is thus divided into twenty-one different sections, and each section is treated as a separate building in the preparation of floor plans and in carrying out operations on the site. The buildings are always referred to by their building numbers, shown on the plot plan in *Fig.* 1. The twenty-one buildings have been divided into seven groups of three buildings each, and a foreman has charge of each group, and is directly responsible to a master foreman. Each foreman has a small office, located in close proximity to the group under his particular supervision, and these offices connect by telephone with the superintendent's office. In this way operations have been carried on simultaneously over the entire site. One thousand men were at one time engaged in excavating, filling, and driving piles. There are four railroad tracks, totalling a mile and a half in length, which traverse the site. A switching locomotive is

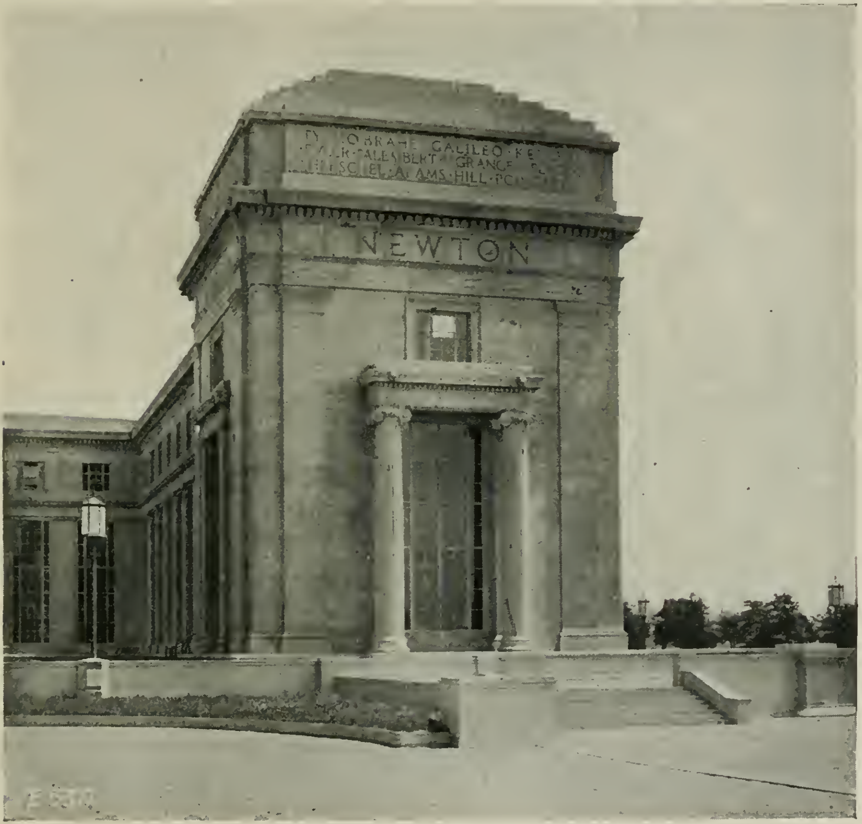


Fig. 2. Detail of Pavilion showing Principal Court Face.
NEW BUILDINGS FOR THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MASS.

operated exclusively for hauling immense amounts of building materials to different portions of the grounds. Fifty-three thousand yards of fill were distributed over the area of the courtyard in order to raise the grade five feet above the River Esplanade, and in addition some thirty-five thousand yards were deposited over the remainder of the lot. One thousand tons of steel have been used on the ground. A few statistics, giving the large quantities of materials used in the buildings, may also be of interest as indicating the magnitude of the work accomplished.

Since the beginning, and during working hours, material of different kinds has been delivered to the job at the rate of one ton per minute. Forty thousand cubic yards of concrete have gone into footings and framework, and one million six hundred thousand square feet of wood forms have been necessary to receive the concrete. Thirty-five hundred tons of reinforcing steel have been required for the concrete, and twenty-two thousand piles have been driven—which approximate five hundred and seventy-five thousand linear feet. Two hundred and fifty thousand cubic feet of limestone have been used for exterior facing, together with six hundred thousand face brick in the interior court-yards. The common bricks used for backing up the exterior walls aggregate

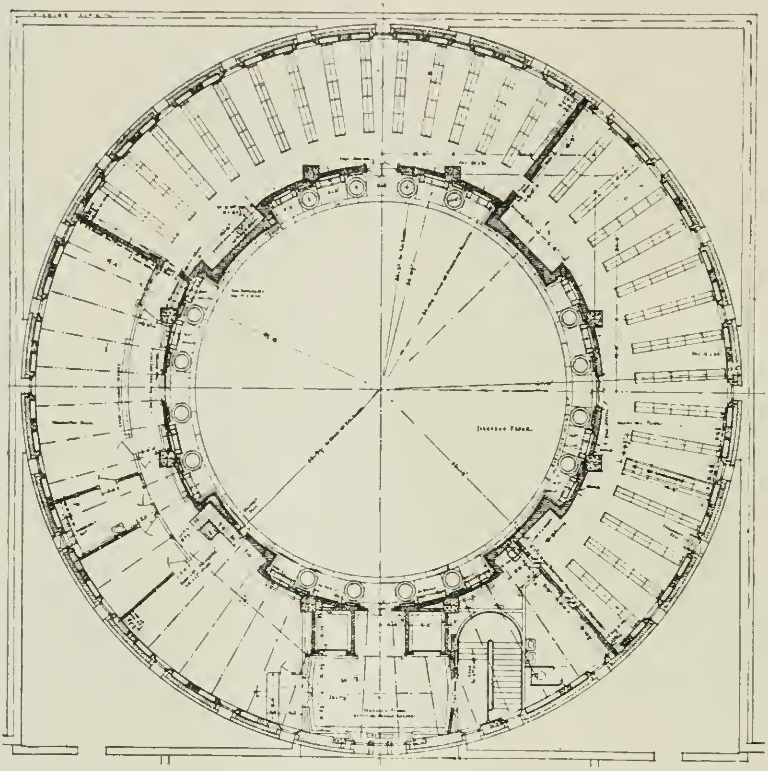


Fig. 3. Library, Fifth Floor Plan.
New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

over three million. One hundred thousand square feet of metal window frames and sash have been installed and five hundred thousand square feet of interior partitions erected.

By adopting reinforced concrete construction it has been possible to carry out the erection of the skeleton framework as one complete operation, thus allowing the masonry to proceed at the base of the buildings before the upper floors were stripped of their concrete forms. As the masonry work rose it gave an opportunity to install the steel window-frames. In this way one operation followed closely on the heels of the preceding ones, and thus a great deal of time was saved.

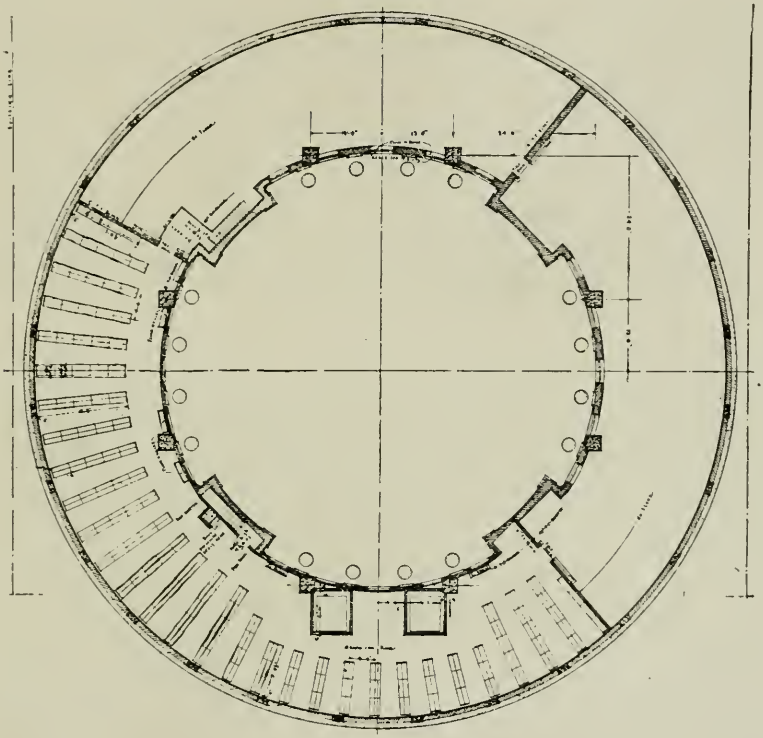


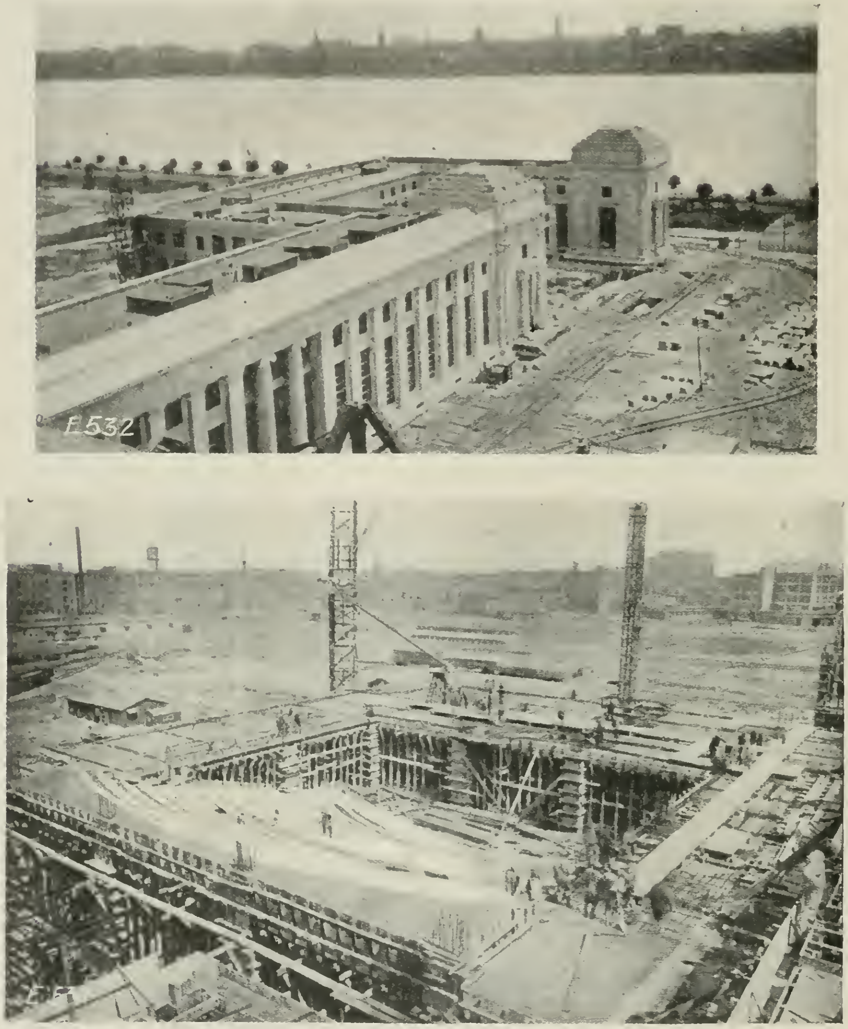
Fig. 4. Second Tier Stack Plan.

New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

The Construction of the Dome.

Principal among the interesting features of construction of the new buildings for the Massachusetts Institute of Technology is the great dome, which rises above the central building, and is at the same time its crowning architectural feature and the most interesting instance of reinforced concrete framing to be found in the entire group.

The dome structure and the five-story building on which it rests are faced with Bedford Limestone, in harmony with the other buildings. The supporting structure, built entirely of reinforced concrete, and following the line of the architectural design, is in the form of two tiers of cylinders or drums, the upper drum surmounted by the dome proper. The lower half of the dome is formed with steps, and the upper half is a truncated sphere, with a skylight in the flat top to admit light to the library reading-room below.



Figs. 5 & 6. The Dome in Course of Construction.
New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

The drums are supported on two circumferential rows of columns, the outside row of the lowest drum resting on a ring girder which in turn rests upon the beams of the fifth floor of the main building. The outside row of the upper drum also rests on a ring girder, which spans the radial beams connecting the outer and inner columns of the lower drum. The inner columns of both drums, eight in number, are continuous with the columns of the main building below. Ring girders support both the upper and lower planes of the spherical portion of the dome. The stepped portion of the dome is formed in reinforced concrete slabs, resting on radial inclined girders spanning the outer and inner columns of the upper drum. The slab varies in thickness from 5 in. at the top to 8 in. at the bottom. The reinforcement is in the form of cross-webbing of twisted rods.

The top of the dome is 147½ ft. above the general level of the site and 65 ft. above the parapets of the adjoining buildings. The lower drum is 120 ft. in diameter and the upper drum 108 ft. in diameter. The curved, or spherical, section of the dome is 70 ft. in diameter.

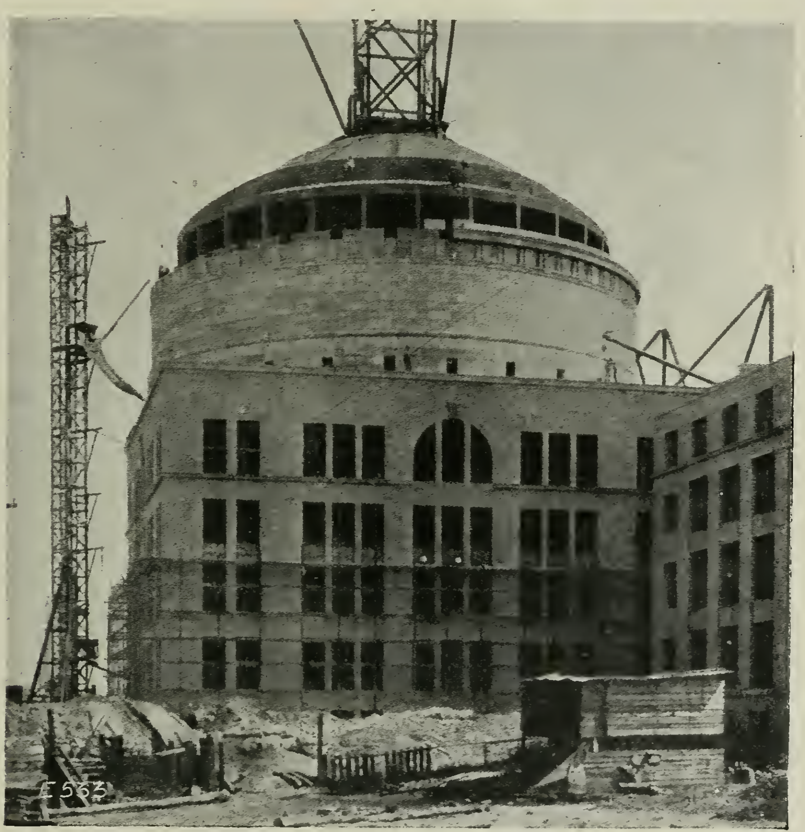


Fig. 7. The Dome in Course of Construction.
New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

The structure supporting the dome is remarkable in that it, inside, suggests in no way the large circle of the dome above, but is utilised for various important purposes, including an entrance-hall; a crane runway, one bay wide, in the basement and first story, extending the full width of the building; a lecture-room in the second and third stories, which will seat five hundred and fifty people and has only two free standing columns exposed; and, on the fifth floor,

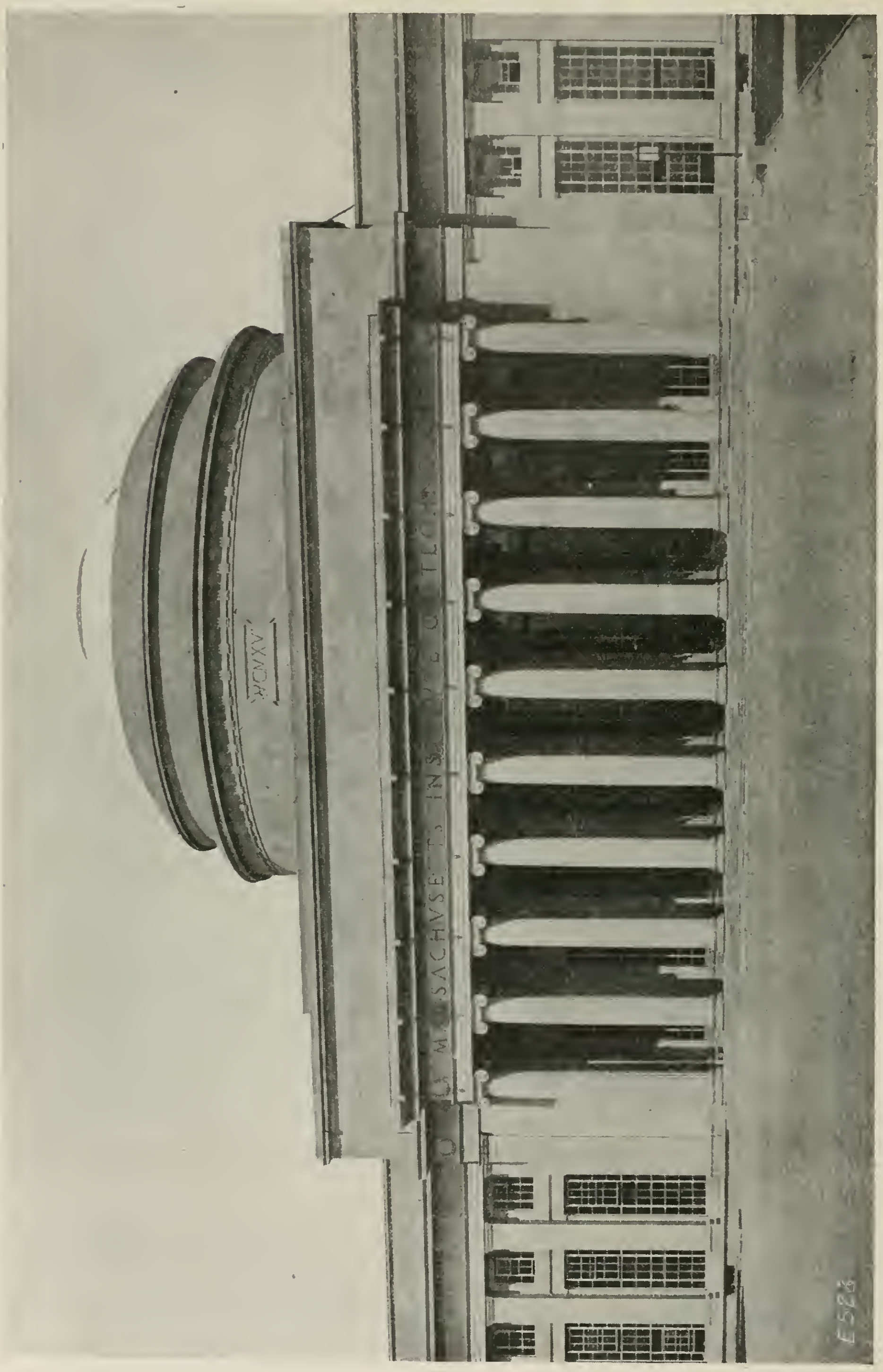


Fig. 8. General View of Dome and Main Portico.

New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

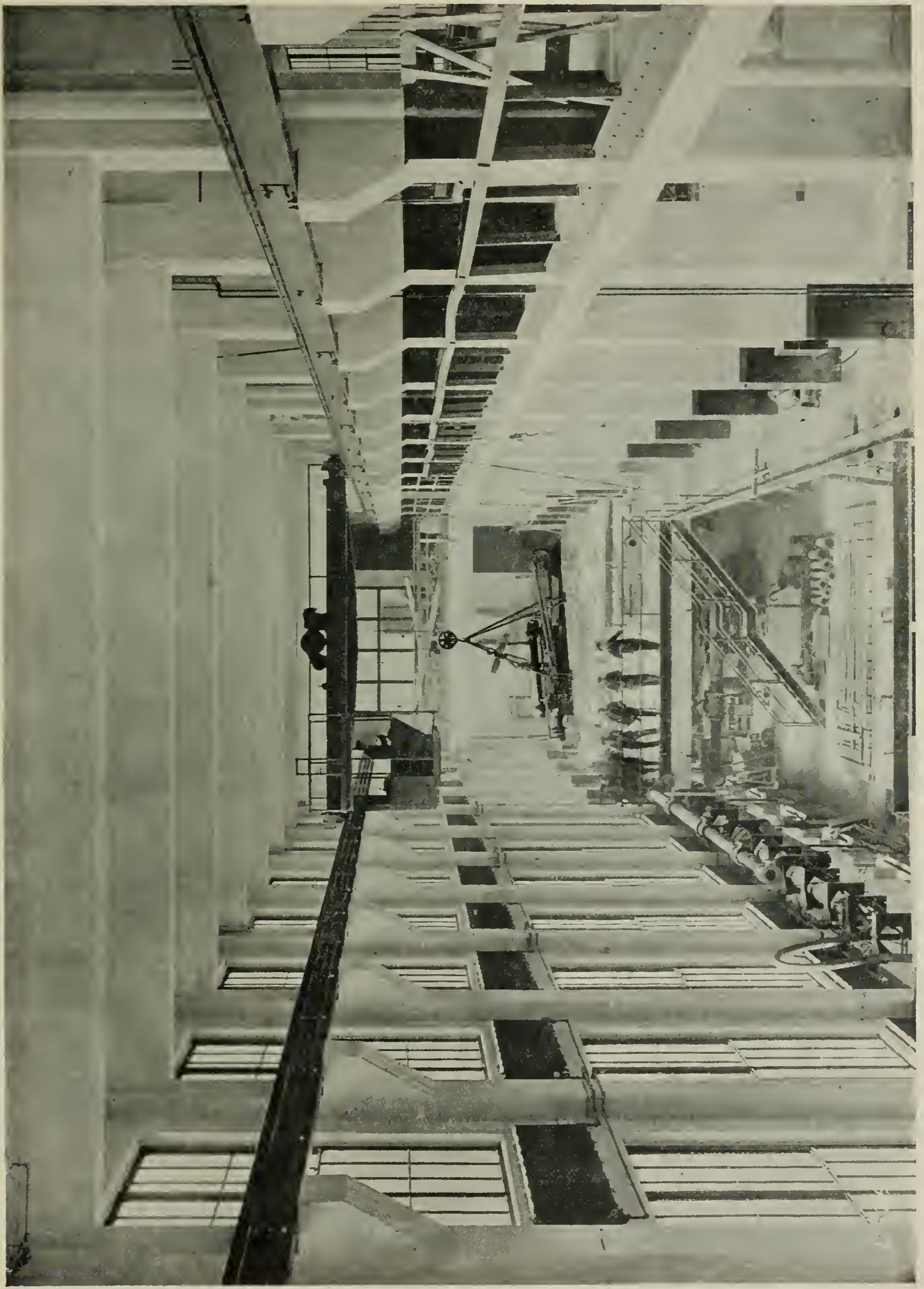


Fig. 9 The Hydraulic Laboratory.

New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

the great circular library, directly beneath the dome, with a reading-room 70 ft. in diameter and 70 ft. high, and stack space for 350,000 volumes.

In the Pratt School of Naval Architecture (Building No. 19 on the plot plan), to be located on Massachusetts Avenue immediately beyond the point at which the façade extending along that street now stops, and which will probably be the first of the future additions to the main buildings to be erected, a larger auditorium, seating two thousand people, will be provided.

The portion of the main study buildings now built provide facilities for two thousand students, and the space contemplated in the plans for future additions will more than double that capacity.

The present scheme provides internal partitions of an easily removable nature, so that class-rooms or laboratories can be enlarged or made smaller, as necessity demands. The big central library and the administrative offices, under the dome, are centrally located for both present and future development.

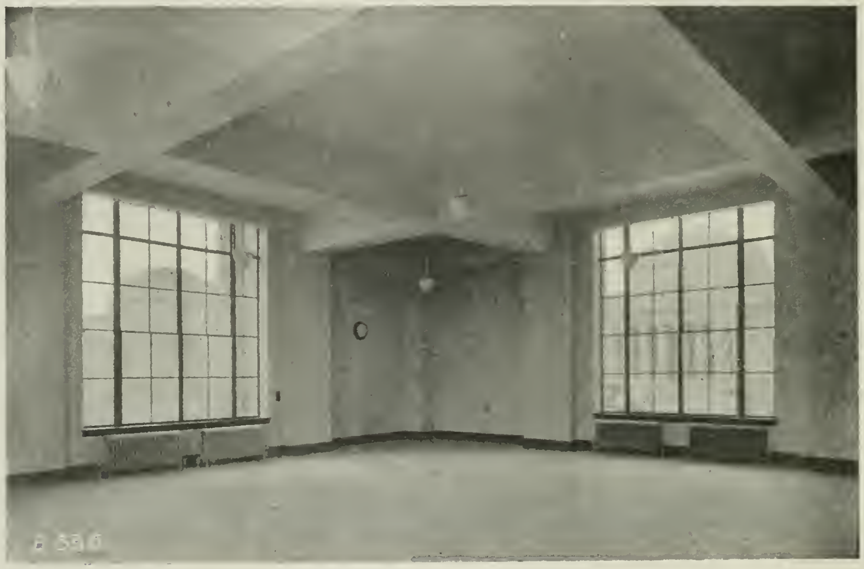


Fig. 10. A First Floor Room in Building No. 2.

New Buildings for the Massachusetts Institute of Technology, Cambridge, Mass.

The study group of buildings being located on the western half of the site leaves the eastern half available for the dormitories and other student buildings, giving them a retired situation, where boating and athletic interests can be easily maintained. This portion of the site is also conveniently near a subway station, making it easily accessible from Boston.

In this student group the Walker Memorial has been located on the main axis, facing upon the Esplanade, with dormitories on either side. In the rear of the Club House is an open court utilised for tennis-courts, and the athletic field extends the remaining depth of the site, with other dormitories and a gymnasium fronting the court on both sides.

The Institute will naturally grow to the east, and in this event the student group of buildings might become the central axis of a future group that may extend along the entire Cambridge side of the water-front, from bridge to bridge.

While the Walker Memorial and the dormitories grouped about it have not yet been started, work is well advanced on the dormitory group located still further to the east.

The President's House is located facing on the River Esplanade in the angle inclosed by this dormitory group, the garden extending out at the back, and filling out the rest of this quadrangular area. The students' Club House—the Walker Memorial itself—is also soon to be started.

While these buildings, on the river side at least, are to be constructed in the same manner and faced with the same material as the study group, it was felt that a distinctly more residential type of architecture, with an entirely different scale, was necessarily to be adopted in their design.

The architect for the building was Mr. Wm. Welles Bosworth, of New York, whilst the engineering corporation selected to carry out the work was the Stone Webster Corporation, Boston.

RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

Continued from September issue, p. 491.—ED.

PART IV.

SHEAR TESTS ON **T** *BEAMS (1914 SERIES).*

(a) Descriptions of Experiments.

A series of test beams was designed by the writer to be tested in shear, special care being taken to ensure that they should fail in this and no other manner, and also that they should prove or disprove as clearly as possible the writer's theory and analysis of inclined compressions.

The series is illustrated in *Figs.* 38 and 39.

It will be seen that it consists of sixteen beams of **T** section, having a flange 12 in. wide, 4 in. thick, and a web 5 in. thick and 8 in. deep.

The tension reinforcement consists of six $\frac{5}{8}$-in. diameter bars in all beams, and the top flange is strengthened with four $\frac{3}{4}$-in. bars.

Beams 1, 3, 5, etc., are provided with fishtails at the ends of the tension bars only, while 2, 4, 6, etc., have large hooks, beams 1 and 2, 3, and 4, etc., being otherwise identical.

The object of this was to make certain whether failure was due to slipping or to insufficient strength of hook or fishtail.

Beams 1 and 2 have no shear reinforcement, 3 and 4 stirrups, 5 and 6 more stirrups, and 7 and 8 still more.

Beams 9 and 10 have inclined bars, 11 and 12 more inclined bars, 13 and 14 inclined bars of greater slope, and 15 and 16 combinations of inclined bars and stirrups.

The steel was commercial mild steel having an ultimate strength 23·8 tons, and an elongation of 29 per cent. in 8 in.

The concrete consisted of—

4 parts crushed flint	$\frac{3}{4}$ in. to $\frac{1}{4}$ in.
2 ,, sand	$\frac{1}{4}$ in. to zero.
1 part Portland cement.	

The latter gave an average of 700 lb./in.^{2} neat tension in seven days.

The beams were made by practical workmen engaged in the construction by the author's firm of Charterhouse Street Cold Storage for the Port of London Authority.

They were made :—

Beams	1–4	……	December 19, 1913
,,	5–8	……	December 23, 1913
,,	9–12	……	January 1, 1914
,,	13–16	……	January 14, 1914

and tested at the City and Guilds Engineering College in 1914, at an age of about four months.

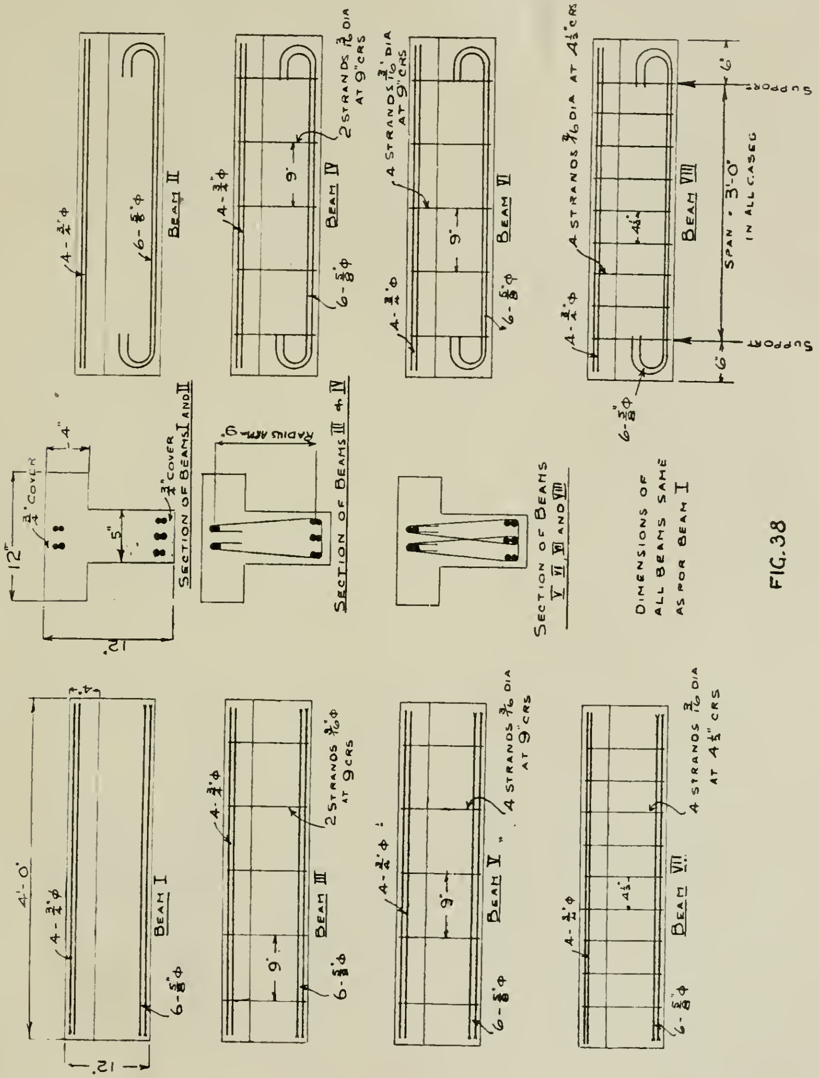

Beam I
Beam II
Beam III
Beam IV
Beam V
Beam VI
Beam VII
Beam VIII
4-½"φ
6-⅝"φ
2 strands 3/16" dia at 9" crs
4 strands 3/16" dia at 9" crs
4 strands 3/16" dia at 4½" crs
9"
4½"
4'-0"
12"
4"
5"
¾" cover
Section of Beams I and II
Radius arm 9"
Section of Beams III & IV
Section of Beams V, VI, VII and VIII
Dimensions of all beams same as for Beam I
Support
6"
Span = 3'-0" in all cases

FIG. 38

The length of the beams was 4 ft., and they were tested by a central point load on a span of 3 ft.

The load was distributed at the supports over a width of 3 in., and at the centre over a width of 6 in. They were tested on a Riehle machine which was found very sensitive and suitable for the purpose.

(*b*) *Calculation of safe shear method of R.I.B.A. Report of* 1911.

	Safe Shear. lb.	Safe Load. lb.
Beams 1 *and* 2.		
Resistance of concrete to diagonal tension = 60 b a ...	2,700	5,400

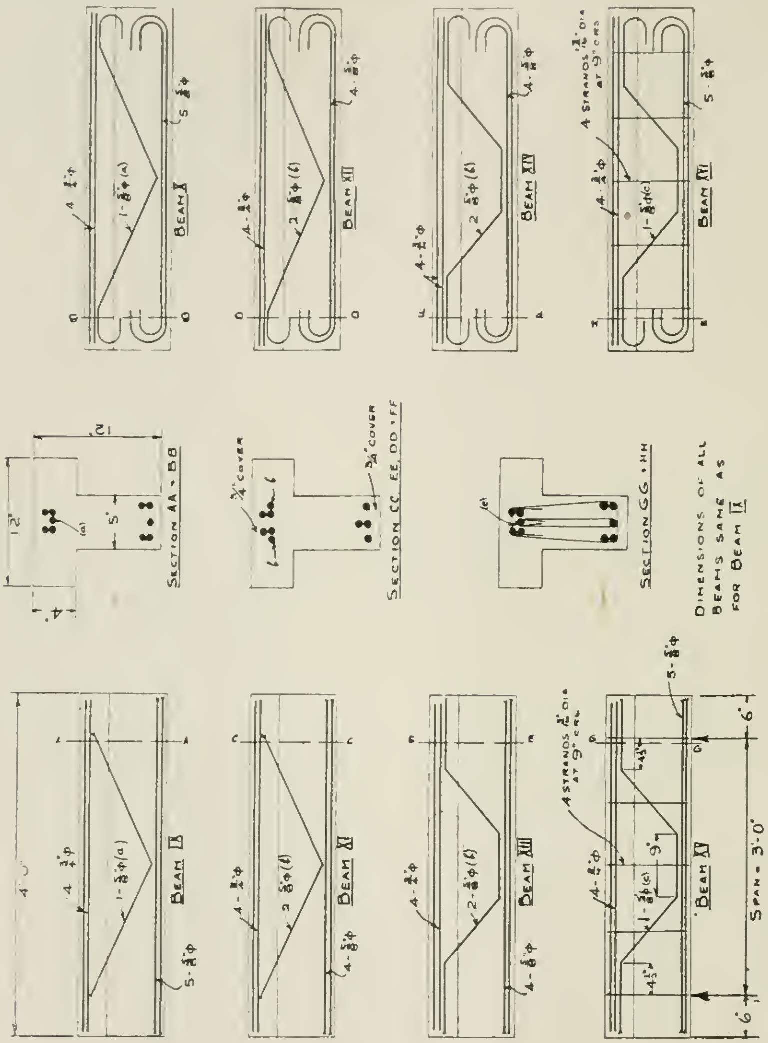


FIG 39

Beams 3 *and* 4.		
Resistance of concrete	2,700	
2 strands $\frac{3}{16}$ in. at 9-in. centres—		
$2 \times 0·0275 \times \frac{9}{9} \times 16{,}000$	880	
	3,580	7,160

	Safe Shear. lb.	Safe Load. lb.
Beams 5 and 6.		
Concrete ...	2,700	
4 strands $\frac{3}{16}$ in. at 9-in. centres ...	1,760	
	4,460	8,920
Beams 7 and 8.		
Concrete ...	2,700	
4 strands $\frac{3}{16}$ in. at $4\frac{1}{2}$-in. centres—		
$4 \times 0{\cdot}0270 \times \frac{9}{4\frac{1}{2}} \times 16{,}000$ ...	3,520	
	6,220	12,440
Beams 9 and 10.		
Concrete ...	2,700	
1 $\frac{5}{8}$-in. bar slope of 1 in $2\frac{1}{4}$—		
$0{\cdot}3 \times \frac{4}{9} \times 16{,}000$ ...	2,130	
	4,830	9,660
Beams 11 and 12.		
Concrete ...	2,700	
2 $\frac{5}{8}$-in. bars slope of 1 in $2\frac{1}{4}$—		
$2 \times 0{\cdot}3 \times \frac{4}{9} \times 16{,}000$ ...	4,260	
	6,960	13,920
Beams 13 and 14.		
Concrete ...	2,700	
2 $\frac{5}{8}$-in. bars at 1 in 1·42—		
$2 \times 0{\cdot}3 \frac{16{,}000}{1{\cdot}42}$ ...	6,780	
	9,480	18,960
Beams 15 and 16.		
Concrete ...	2,700	
1 $\frac{5}{8}$-in. bar at 1 in 1·42 ...	3,400	
4 strands $\frac{3}{16}$ in. at 9-in. centres ...	1,760	
	7,860	15,720

(*c*) *Calculation of safe shear by L.C.C. Rules* (Reinforced Concrete Regulations, L.C.C. (General Powers) Act, 1909).

64.—The vertical shear taken by the concrete only shall be calculated on the compressed area of the web or on the web area for a depth equal to the arm of the resistance moment of the beam. The intensity of the shearing stress shall not be greater than the values given in Regulation 42.

65.—Where the vertical shear is taken by the concrete only, in accordance with Regulation 64, the ends of 50 per cent. of the bars of the tensile reinforcement shall be inclined across the neutral plane of the beam, and shall be carried through a depth equal to the arm of the resistance moment, or the whole of the bars shall be carried through to the ends of the beam (see Regulations 87 (*c*) and 88 (*c*)).

66.—If the shearing stress at any cross-section, calculated on the concrete alone, is in excess of the permissible shearing stress, the whole shear shall be provided for by the tensile resistance of the shear or web reinforcement acting in conjunction with the compressive stresses in the web, but in no case shall the ratio $\frac{S}{b_r d}$ exceed three times the shearing stress given in Regulation 42 (*a*), where—

b_r = mean *breadth* of the *rib* of a tee beam or the *breadth* of a *rectangular* beam;

d effective *depth* of the beam;

S = total vertical *shearing* force at any cross-section.

(Also see Regulation 84).

It will be seen that diagonal tension in concrete is not to be taken in combination with bent-up bars and stirrups (Regulation 66). So in beams 13 and 16 the resistance of bent-up bars and stirrups only is to be allowed. In beams 3 and 4 the stirrups give safe shear $= 2 \times 0{\cdot}0275 \times 16{,}000 = 880$ lb.

As, however, the concrete gives 2,700, and we have to take either but not both (see Regulation 66), the concrete value only is allowed.

Similarly in beams 3 and 4, 5 and 6. In 7 and 8 the stirrups give a higher result than the concrete, and this value is, therefore, taken.

In all subsequent beams the reinforcement gives higher results than the concrete, and is, therefore, used in the calculations, except in the case of beams 9 and 10, where the steel gives only—

$$0{\cdot}3 \times \frac{4}{9} \times 16{,}000 = 2{,}130 \text{ lb.}$$

and the concrete value of $60\,b\,a = 2{,}700$ is, therefore, used.

Beam Number.	—	Safe Shear.	Safe Load.
		lb.	lb.
1 and 2	60 *b a*	2,700	5,400
3 „ 4	60 *b a*	2,700	5,400
5 „ 6	60 *b a*	2,700	5,400
7 „ 8	4 strands at 4½-in. centres	3,520	7,040
9 „ 10	60 *b a*	2,700	5,400
11 „ 12	2 ⅝-in. bars	4,260	9,520
13 „ 14	2 ⅝-in. bars, slope 1 in 1·42	6,780	3,560
15 „ 16	1 ⅝-in. bar 4 strands at 9-in. centres	3,400 1,760	10,320

(a) Calculation of safe shear by the writer's analysis of inclined compression.

Beams 1 *and* 2.—The beams are evidently subject to a most important direct inclined compression, and the first thing will be to calculate its amount.

Since we have top steel, we will use the analysis of section 2 (page 362, July issue).

This gives us an equation for n at the support.

$$n^3 - n^2 \,.\, 3\,d_1 + n\frac{90\,A\,(d-d_1)}{b} - d\,\frac{90\,A\,(d-d_1)}{b} = 0$$

Substituting—

$d_1 = 1\tfrac{1}{2}$ in.
$d = 10\tfrac{1}{2}$ in.
$A = 4$ $\tfrac{3}{4}$-in. bars $= 1{\cdot}76$
$b = 5$ in.

we get—

$$n^3 - 4\tfrac{1}{2}\,n^2 + n\,\frac{90 \times 1{\cdot}76 \times 9}{5} - 10\tfrac{1}{2}\,\frac{90 \times 10{\cdot}76 \times 9}{5} = 0$$

It will be found that this is solved by—

$$n = 9{\cdot}15 \text{ in.}$$

This gives the horizontal component of the inclined compression—

$$c = 9{\cdot}15 \times 5 \times 300 = 13{,}700 \text{ lb.}$$

Note that causes a stress of $\frac{13{,}700}{6 \times 0{\cdot}3} = 7{,}600$ lb.-in.² on the six bottom bars, which shows that they will not be overstressed, even in beams 11 to 14 when two bars are bent up.

Note also—

$$d - n = 10\tfrac{1}{2} - 9{\cdot}15 = 1{\cdot}35 \text{ in.}$$

Hence tension in top bars at support—

$$t = 600 \times 15 \times \frac{1{\cdot}35}{9{\cdot}35} = 1{,}300 \text{ lb./in.}^2$$

$$T = 1{\cdot}76 \times 1{,}330 = 2{,}350 \text{ lb.}$$

Note that this latter produces an adhesion stress in 5-in. length of 4 $\frac{3}{4}$-in. bars of—

$$\frac{2{,}350}{5 \times 4 \times 5 \times 4 \times \frac{3}{4}} = 50 \text{ lb./in.}^2$$

which is well within the allowable stress.

At the centre section we have $n = 4$ 2 in. (which it is not considered necessary to show here), and the centre of pressure $\frac{4{\cdot}2}{3} = 1{\cdot}4$ down from top (see *Fig.* 40).

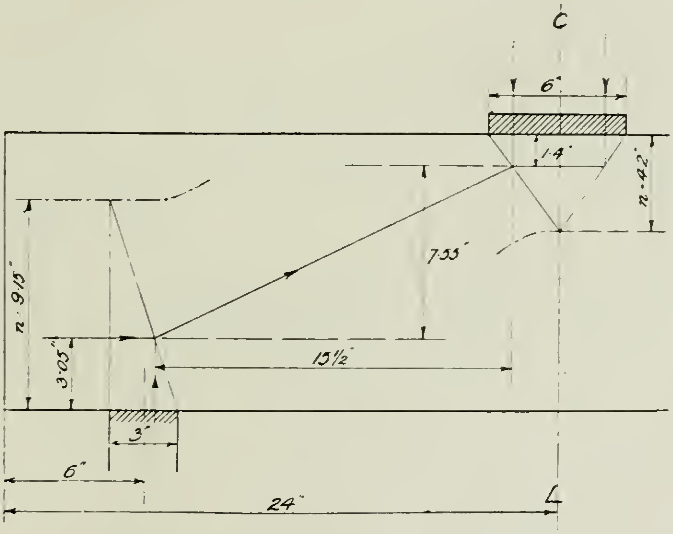


FIG. 40. SHOWING INCLINED COMPRESSION IN TEST BEAMS.

Hence the rise of inclined compression is—

$$12 - \frac{9{\cdot}15}{3} - 1{\cdot}4 = 7{\cdot}55 \text{ in.}$$

and occurs in a horizontal length of 15½ in.

Hence the shear due to this is—

$$13{,}700 \times \frac{7{\cdot}55}{15\frac{1}{2}} = 6{,}670 \text{ lb.*}$$

Coming now to *beams* 3 *and* 4, we have the case of a compression at 45° due to the stirrups superimposed on one at about 30° (direct).

---

* The simple formula $S = 2{\cdot}5 \frac{b\, h^2}{l_1}$ (Part 3, secs. 11A and 17) gives $S = 5{,}200$. The formula was derived for rectangular beams, and a greater rise is obtained with **T** beams. Hence the difference.

Hence we have to follow the treatment given in section 16 (p. 488, September issue) and take the first in full, and so much of the second as will keep the resultant stress below 600.

The shear due to the stirrups is 880 as before, which produces a stress of

$$\frac{880}{a\,b\cos\theta\sin\theta}=\frac{1.760}{9\times 5}=39 \text{ lb./in.}^2$$

in the concrete.

From the construction given in the section referred to, it is found that to keep the resultant stress under 600, the stress in the inclined compression must be kept down to 565 (see *Fig.* 41).

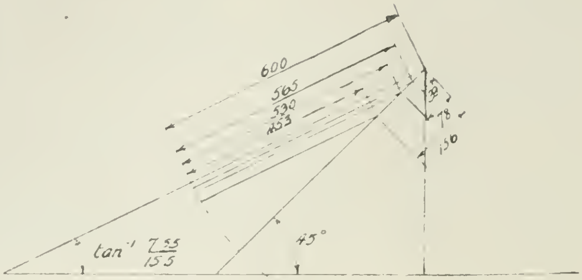


FIG. 41.

Hence shear due to inclined compression is—

$$6{,}670\times\frac{565}{600}=6{,}280$$

Similarly for *beams* 5 *and* 6 shear due to stirrups = 1,760 lb.

This produces concrete stress = 78 lb./in.².

By diagram, stress in direct inclined compression must be reduced to 530.

Shear by inclined *compression* = $6{,}670\times\frac{530}{600}=5{,}900$

Similarly for *beams* 7 *and* 8 shear due to stirrups = 3,520 lb.

This produces concrete stress of 156 lb./in.², direct inclined compression stress must be reduced to 453 shear by inclined compression = $6{,}670\times\frac{453}{600}$ = 5,030.

The stress diagrams for all the above are on *Fig.* 41.

Coming now to *beam* 9, we notice that the inclined bar is in the condition mentioned in section 2 of being insufficiently fixed at its end, and if we consider the vertical section *AA* in *Fig.* 39 just clear of the support, we see that the stress is limited to the efficiency of the hook only. Taking this as one-half of the strength of the bar, we have—

Shear due to bent bar = $0{\cdot}3\times16{,}000\times\frac{1}{2}\times\frac{4}{9}=1{,}065$
Inclined compression ... ... = 6,670

In *beam* 10, the inclined bar is adequately fixed and may be taken in full.

Shear due to bent bar = $0{\cdot}3\times16{,}000\times\frac{4}{9}=2{,}130$
Inclined compression ... ... = 6,670

Similarly the inclined bars in *beam* 11 are badly fixed and give us—

Shear by inclined bars = 2,130
Inclined compression = 6,670

While in *beam* 12 they are fully fixed and give—

Inclined bars ... = 4,260
Inclined compression = 6,670

Note that in the last four beams the shear carried by the bent bars is taken up to the top flange over the support and is transmitted to it vertically. The vertical compression due to this might be treated as a superimposed compression, in virtue of which the inclined compression should be reduced. This has not been done because—

(*a*) The forces are nearly at right angles.

(*b*) The overstressed part would be very near the support, where additional lateral support is given.

Coming now to *beams* 13 *and* 14, a steep inclined compression is produced from the top bend to the support, which we calculate in full and then reduce direct compression to keep within 600.

We have—

Resistance due to inclined bars

$$=2\times 0{\cdot}3\times 16{,}000\times\frac{1}{1{\cdot}42}=6{,}780 \text{ lb.}$$

Stress in concrete due to this is—

$$\frac{6{,}780}{a\,b\cos\theta\sin\theta}=\frac{6{,}780}{9\times 5\times\frac{1}{2{\cdot}24}\times\frac{2}{2{\cdot}24}}$$

$$=375 \text{ where } \theta=\tan^{-1}\frac{9}{4\frac{1}{2}}$$

Graphically in *Fig.* 42 we find this requires the direct compression to be reduced from 600 to 260 and gives—

Resistance due to inclined compression

$$=6.670\times\frac{260}{600}=2{,}890$$

In *beams* 15 *and* 16 we take in full the resistance of stirrups and bent-up bar, calculate the compression due to these, and by means of the stress diagram find the permissible stress in the direct inclined compression. This is just as before, except that this time we have three forces in our vector diagram.

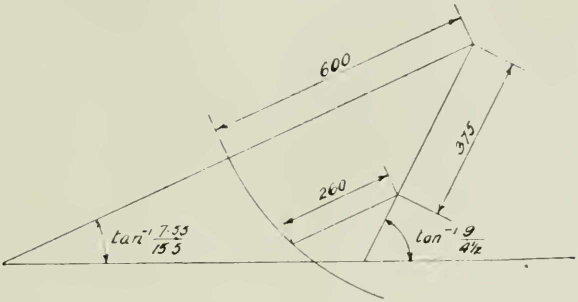

600
375
260
$\tan^{-1}\frac{7{\cdot}55}{15{\cdot}5}$
$\tan^{-1}\frac{9}{4\frac{1}{2}}$

FIG. 42.

Resistance due to stirrup = 1,760
Concrete stress due to this = 78 at 45°
Resistance due to inclined bar = 3,390
Concrete stress due to this = 187 $\theta=\tan^{-1}\frac{9}{4\frac{1}{2}}$

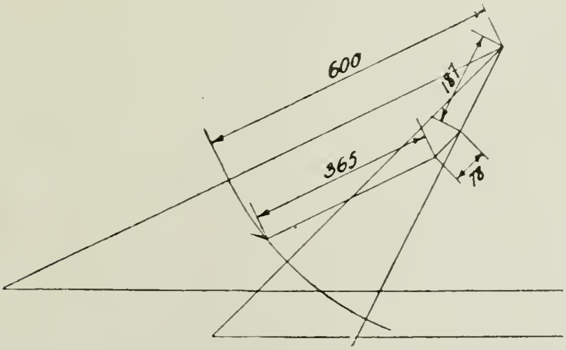


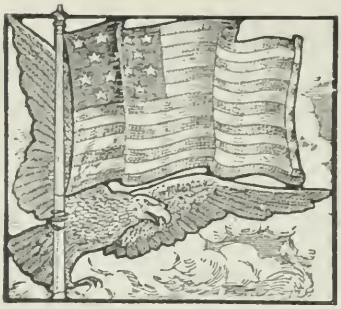
FIG. 43.

Hence by diagram in *Fig.* 43, stress in direct inclined compression is 365.

Resistance due to inclined compression

$$=6{,}670\times\frac{365}{600}=4{,}060$$

(*To be continued.*)



CONCRETE ROADS IN AMERICA.—OVER 3,000 MILES LAID IN THE PAST TWO YEARS.

A Review of the Papers presented at the Second National Conference on Concrete Road Building, held in Chicago in February, 1916.

By W. MATTHEWS-JONES, M.Inst.M. & Cy.E.
City Surveyor and Engineer of Chester.

Continued from September issue, page 476. In another part of this issue will be found the Paper read by Mr. Van Scoyoc to which we referred last month.—ED.

CONCRETE PAVEMENTS IN SOUTHERN CITIES.

THE paper dealing with the question of "The Development of Concrete Pavements in Southern Cities"—Experience in Marcon, Georgia—by J. J. Gaillard, the City Engineer, deserves close attention, and for this purpose I quote rather freely from his paper, and have numbered such paragraphs.

Better Highways.—1. "The building of better highways is a subject of the very greatest importance to every true and loyal son of this grand country. For these highways make the stranger of yesterday the neighbour and friend of to-day."

2. "There is no better way in which to use the ratepayer's money than for street and road improvement, for, after all, the highway is the only mode of intercommunication free to all alike."

3. "Marcon also has some excellent brick pavement and some of the best asphalte I ever saw, but you can judge by the comparison of yardage of the different kinds we put down last year and what we have contracted for this year which kind we prefer. From July of last year up to the present we have laid 12,000 sq. yds. of brick, 19,000 sq. yds. of asphalte, and 108,000 sq. yds. of concrete. For this year we have contracted for about 75,000 sq. yds. of concrete."

4. "In the South, concrete pavement is still in its infancy. A little more than four years ago, when I laid our first concrete pavement, it was considered by most of our City Fathers as a very risky experiment, and quite a considerable number of our most influential citizens very strenuously objected to the city's money being thus foolishly expended. At that time the alleys in the business section of the city were rough, muddy, and in a most insanitary condition. While the residential sections of Marcom consist of beautiful and undulating slopes, affording perfect natural drainage, Marcon being the head of navigation of the Ocmulgee, the business portion is near the river, therefore almost level."

5. "I insisted that these alleys be paved, and with concrete. There was much opposition, since concrete was looked upon as being too much of an experiment. But as concrete was much cheaper than the other materials, the work was at last begun, the mixture being 1 : 2 : 4. After two or three of these alleys had been paved and opened up to the traffic for a few days, the public generally began to realise that the money had been well expended; and property holders along other alleys petitioned the City Council for this kind of pavement. In eight months nearly every alley in the business section had been paved, and to-day they are smooth, hard, clean and in perfect sanitary condition. Though four years old and subjected to the very

heaviest traffic, they have needed no maintenance whatever. The pavement in our alleys is concave. We had a very important street, one block of which was so muddy in wet weather that, for weeks at a time, it had to be closed to traffic. The Street Department had from time to time hauled off the mud, replacing same with good material; but in a short time this would become as bad as that which had been removed. The nature of the soil was such that it was considered unfit for the subgrade of any type of pavement. At this time we had opened up two of our concrete alleys to traffic, and I was allowed to use concrete to pave this street. While my 1 : 2 : 4 mixture had proved satisfactory in the alleys, I thought it best to make assurance doubly sure, so used a mixture of 1 : 2 : 3. On account of the treacherous nature of the soil, I gave the pavement what would seem an abnormal crown. The street being 40 ft. wide from curb to curb, I made the crown 14 in. instead of 8 in. This pavement was 8 in. thick the entire width, and now, though four years old, is in perfect condition, with the exception of one place 12 in. in diameter, and it is so slightly worn as to really need no attention at present."

Repairs to Gas Mains, etc.—6. "It is of interest to note that last year we had to allow the Gas Company to make 122 holes in two blocks of this pavement to locate and repair leaks in the gas main, these holes ranging from 3 in. to 4 ft. We patched these holes with our city force, and to-day it is almost impossible to detect the places patched. After finishing this street, we had three others concrete paved, two of which carry street car lines their whole length. None of these streets has needed any maintenance, with the exception of a little Tarvia 'A,' with which we recently fixed up expansion joints at a very slight cost."

Covering with Tarvia.—7. "Two years ago we laid eight blocks in a residential district under the same specifications, with the exception that the crown was 8 in. and that the pavement was 6 in. thick at the curb and 8 in. thick at the centre. After this street had been opened to traffic about one year, we covered same with Tarvia 'A,' applying one gallon, at a temperature of 250 degrees, to every three square yards, and while hot, covering same with granite sand, allowing traffic on it immediately, wearing the sand into the Tarvia, making a dustless, noiseless carpet. This, in my opinion, makes an excellent street, having advantages of an asphalte pavement, and at the same time being more durable and less expensive."

Maintenance of Tramway Tracks.—8. "After examining various types of pavements in quite a number of cities, and after wrestling with the question for four years in Marcon, I have come to the conclusion that the item of supremest importance is the stability of the car tracks. Now the question naturally arises: What is the proper way to treat the car tracks to insure the desired conditions? It is my opinion that the solution of the question is a concrete pavement. This in the end will, I believe, be economical for the traction company. The concrete being under the base of the rail, firmly gripping the flanges, and being embedded under the ball, the ties can safely be placed much further apart, making quite a saving in the item of timber. The rail being perfectly steady, lamination will be prevented; light and inexpensive angle bars can be used, and the perfect grade and alignment will reduce the wear on the equipment, and the item of maintenance will be almost eliminated. The concrete being brought to the top of the rail, a little truck made of two wooden rollers with flanges the same depth and a little broader than the flanges of the car wheels is rolled along the track, making grooves for the car flanges. This little truck not only serves the purpose above set forth, but acts as a portable platform from which the finishers can work. I know of no paving comparable to concrete where street car traffic is carried on. The flange grooves can be so constructed that even narrow-tyred vehicles will not skid when crossing the track even at acute angles."

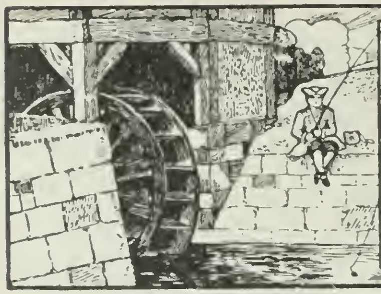
Laying Concrete Pavements.—9. "Without going into minute details, I will mention that in laying our concrete pavement we observe the following:—After bringing the sub-grade to a true surface we rolled it with a ten-ton roller, replacing any spongy or other bad places with some good material. If the ground is dry we thoroughly wet it, then place the concrete, which is of the following mixture: one part tested Portland cement, two parts clean, coarse, sharp sand, and three parts hard crushed granite, perfectly clean, ranging in size from one-fourth inch to one and one-half inches, thoroughly mixed in a batch mixer which has a boom and bucket for delivering same. I have found from experience that it is better to finish this pavement with a light iron cylinder roller about 8 in. in diameter, 4 ft. to 8 ft. long, with a handle long enough to reach from the curb line just past the centre of the street, the long rollers being used for the main part of the work and the short ones in finishing around intake basins, curb corners, and other difficult places. Next to the curb we use one-half inch sandwich joints, and for our transverse joints—which are placed every 25 ft.—we use one thickness of tar paper, leaving this tar paper about $\frac{1}{16}$ in. below the finished surface, and as soon as the concrete is set, and the little crack shows at this joint, we paint same with Tarvia 'A,' heated to about 250 degrees. This Tarvia thoroughly fills in this crack, preventing dust or sand from packing into same. I find that by following this method it enables us to get a perfectly true grade, obviating the wavy effect on concrete pavements. Of course, we keep our pavements protected by covering with sand, which is kept wet for at least eight days, and we also keep the street blocked from traffic for at least fourteen days in the summer and as much longer as necessary when the weather is cold or the atmospheric conditions require. In my opinion, concrete pavement in the South is yet in its infancy, but the profession is beginning to realise the great advantages of this material, and in the near future the demand for it will constantly increase. Quite a number of towns and cities whose officials have seen our Marcon streets are now adopting concrete for their pavements."

What strikes me most are paragraphs 6 and 8. The former deals with the vexed question of *breaking up concrete roads for repairs to gas, water, and other mains*, and here we find that Mr. Gaillard has no difficulty in making good such pavements that have been disturbed. Personally, I have had no experience yet of having to make good any of my concrete roads after such openings have been made for repairs; but I can say that I have had considerable experience in making good openings which have been made in concrete footways, and I quite concur with Mr. Gaillard that if this work of repairs is tackled in a proper manner one should hardly be able to detect where such have been made. Another thing I perhaps ought to mention here is that, before constructing a concrete road, I generally serve three months' notice on the Electricity Department and the Gas and Water Works authorities that "such-and-such a street" is about to be constructed of concrete, and in this notice I say that if they have any services to be renewed, altered, or repaired, they must at once proceed with the work, and I undertake not to charge any of the departments concerned for temporary reinstatement. In fact, I go further, and keep such trenches as may have been opened after they are filled in in such repair for the safety of the traffic until I have an opportunity to proceed with my work of concrete construction. This gives an encouragement to these three departments to proceed with any work they may have in hand, as it relieves them of the cost of making good the road surfaces which have been disturbed. It also has another good effect, inasmuch as it allows the disturbed earth in these trenches to again become consolidated before I proceed with my work. Personally, I would like to go further than this—viz., to serve notice on each and every property owner in a street which is to be laid with concrete, saying that he must have the drain connections from his property to the sewer examined, and, if found faulty, they must be put right; but as this would mean a costly and lengthy job, I have refrained from asking for this up to now, but I can see the time coming when it will have to be done, whether by the property owners or by the local authorities I am not in a position to argue. Of course, where new streets are laid out and new buildings erected, it is up to the local authorities' officials to see that in these days of modern engineering science such drains are properly and well laid. What I refer to above are streets that have been made and built upon, say, before the year 1900, when, I venture to think, the same strict supervision and attention was not given in the majority of towns to matters of this description as is done to-day.

Dealing with paragraph 8, here is something tangible and interesting to the road surveyor who has to do with the *laying and maintenance of tramway tracks through city streets.* I think Mr. Gaillard has gone a long way to solve the tremendous and often worrying conditions that have to be met in connection with tramway work; and again I would like to venture an opinion, which is that all tramways will gradually be done away with, and when good, sound, and permanent concrete roads are constructed, trackless cars will come into more extensive use. If my conjecture is accurate, the annoyance of, say, one-quarter or one-third of the carriageway being solely occupied for the tram service, often to the detriment of the two portions of the road surface on either side of the track, will cease. Again, where the public authorities own the tramways, they will not have to face the enormous charge which they do now in the maintenance and upkeep of the track, but by arrangement with the Council an annual charge could be fixed to defray any extraordinary expenditure that the highways authority may have to meet on regular tram and 'bus routes.

(*To be concluded.*)

In the next and concluding portion of this Review an interesting statement will be found giving the relative cost of all classes of roadways compared with concrete.

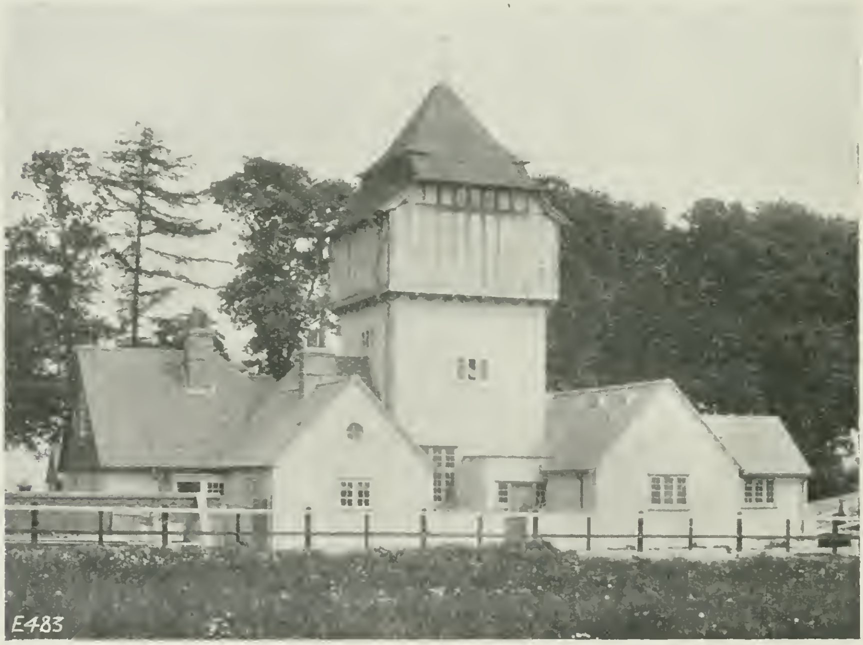


ILLUSTRATIONS OF REINFORCED CONCRETE WATER TOWERS.

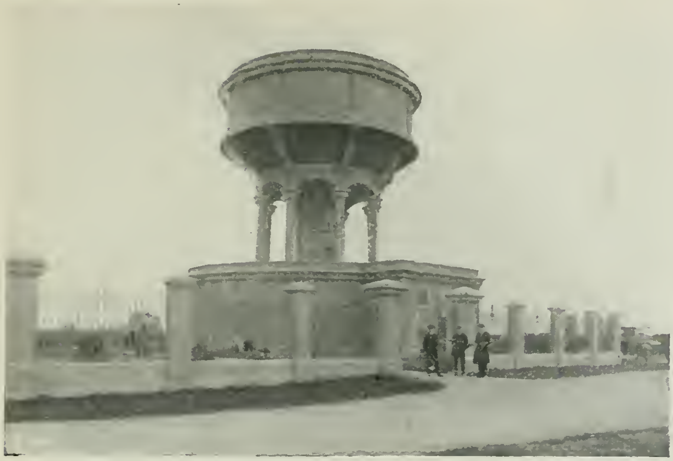
The following series of illustrations is continued from our September issue in order to show the applicatton of reinforced concrete to water tower construction.

The firms whose systems of reinforcement have been used have been dealt with alphabetically.—ED.

Milton Hill.—This tower embodies two tanks, a lower one 20 ft. 6 in. square, of 20,000 gallons capacity, and an upper one immediately above 12 ft. 6 in. square, of 7,500 gallons capacity. The depth of water in each tank is 7 ft. 6 in. The tanks are placed concentrically, and a central reinforced concrete shaft gives access to the upper portion of the structure. The upper tank is carried on beams supported entirely on the outer walls of the lower tank, the central shaft of the lower tank being left clear of the upper tank in order to avoid the possibility of any load coming upon it.



MILTON HILL WATER TOWER.

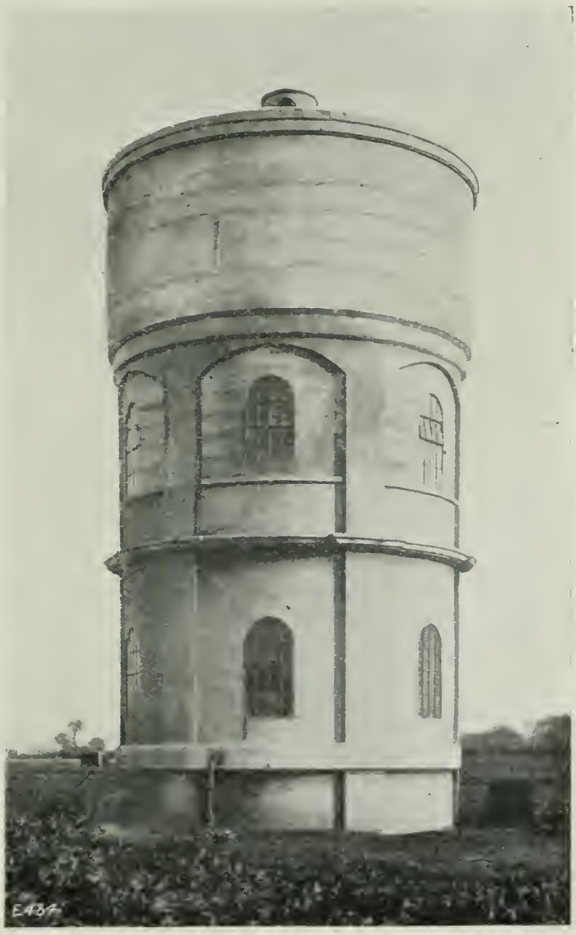


WITHERNSEA WATER TOWER.

Withernsea.—This tower has only recently been completed and was opened in July of this year. It was constructed for the Hull City Waterworks, and it is interesting from the fact that a ground reservoir (of 300,000 gallons capacity) is combined with an elevated tank (of 100,000 gallons capacity) into one structure.

Lancing.—The third illustration is that of a water tower erected at Lancing for the London Brighton and South Coast Railway Co. In this instance the tank has a capacity of 40,000 gallons, with an internal diameter of 27 ft. and a depth of 13 ft. 6 in. The bottom is in the shape of a dome 25 ft. span, with a 4 ft. rise, and consists of a slab 6 in. thick. The walls, 6 in. thick, support the dome-shaped roof, 27 ft. span with a 4 ft. rise. The roof slab is 4 in. thick, and has a lantern tower at the crown. The tank is carried on an arched circular beam which is supported on six rectangular columns 36 in. by 9 in. The columns are in turn enclosed by panel walls 4 in. thick, which form the walls of the Pump House at the ground level.

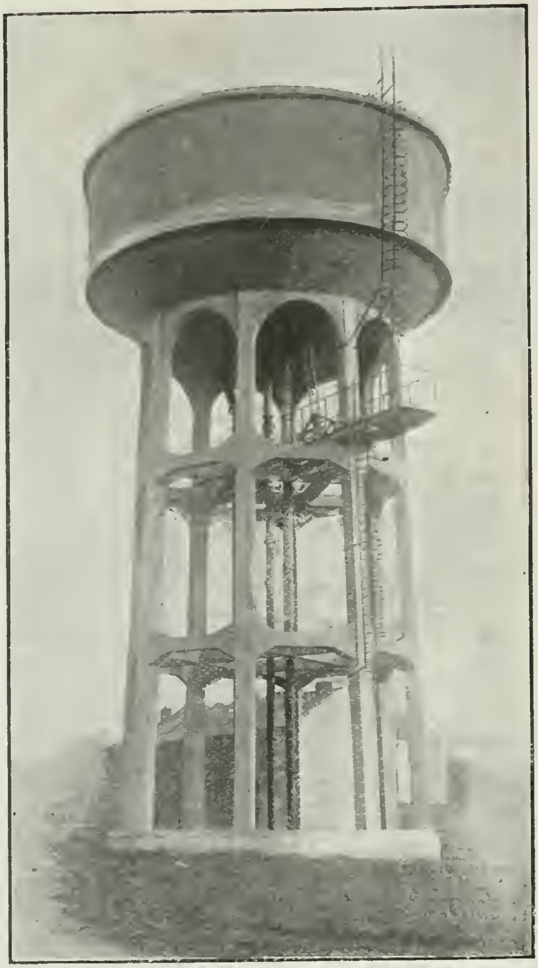
The Kahn system of reinforcement has been used in these three water towers.



LANCING WATER TOWER.

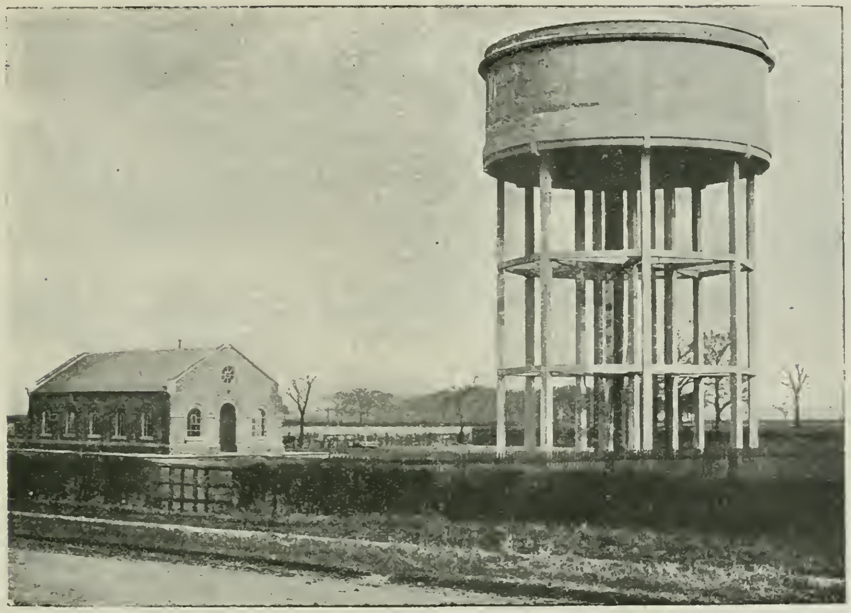
* * *

Portsmouth Salt Water Tower.—Forms part of the Portsmouth salt water system for street watering and sewer flushing, and was built in 1915 under Mr. W. Ward, borough engineer. Capacity: 60,000 gallons. Total height, 74 ft. 9 in.; tower 60 ft. 3 in. high to under side of reservoir, the latter being 32 ft. in diameter by 14 ft. 6 in. deep.



PORTSMOUTH SALT WATER TOWER.

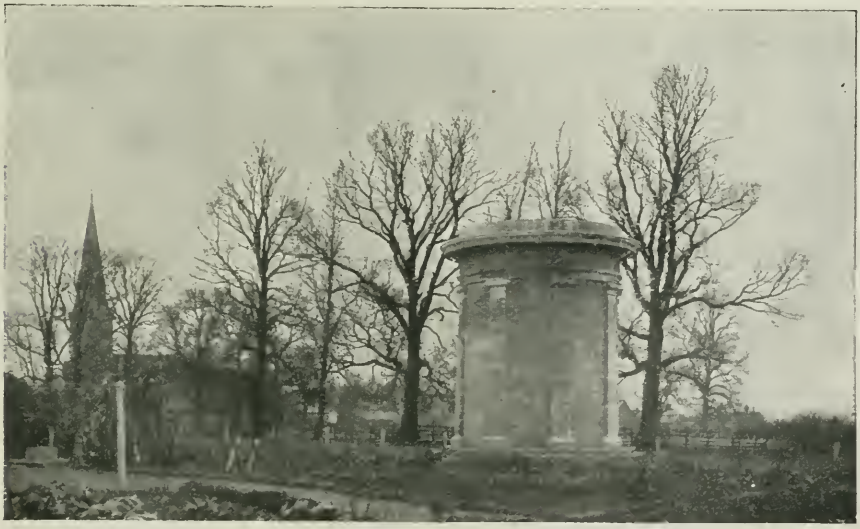
Hatfield, near Doncaster, Water Tower.—Capacity: 150,000 gallons; reservoir, 45 ft. diameter inside, and water depth of 15 ft. Tower 50 ft. high to bottom of reservoir. A novel feature is the provision of an inner storage compartment to enable the supply of water to be maintained while the main tank is being cleansed. The tower forms part of the Thorne and district waterworks undertaking executed under Messrs. Fairbank and Son, M.Inst.C.E., of York.



Pumping Station and Water Tower, Hatfield, near Doncaster.

Ridgmount.—Erected in 1912 for the Duke of Bedford, from the designs of Messrs. D. Balfour and Son, M.Inst.C.E., of Newcastle-on-Tyne and London, in connection with the Ridgmount and Crawley water supply scheme. Capacity: 40,000 gallons.

The Mouchel-Hennebique system of reinforcement was applied in these three last examples given.



Water Tower, Ridgmount.

PROPORTIONING CONCRETE BY MECHANICAL ANALYSIS.

By H. S. MANISTY, R.E. (S.R.), A.M.Inst.C.E.

The question of the proportioning of concrete by mechanical analysis is one which deserves greater attention than has hitherto been accorded to it, and the tests conducted by the writer of this article will no doubt be of interest to our readers.—ED.

THE above method was worked out by Messrs. Fuller and Thompson, whose results are published in the *Transactions of the American Society of Civil Engineers,* Vol. 59.

The following is an explanation of the method and the results of tests made by the writer at the University of California.

The system is valuable as a help to arrive at the correct proportions of sand and stone, not only in reinforced concrete work where quality is of first importance, but also in mass concrete where a small percentage saving of cement means a large saving in total cost.

It is well known that a mixture of different sized particles in certain proportions results in a mass with less voids than a mass of particles of any one size.

Messrs. Fuller and Thompson state the proportions of each size particle as a Percentage Mechanical Analysis, which is arrived at by passing a known weight of material through a series of screens and expressing the amount passing each screen as a percentage of the total.

They also state, as the result of a large series of experiments, that to arrive at concrete of greatest density the proportion of each size particle should agree with a certain curve. This curve does not vary much for different classes of material. It consists of an ellipse for the sand portion and a straight line tangent to the ellipse and passing through the junction of 100 per cent. and largest size stone.

Data for plotting this curve for various mixtures of stone, sand, and gravel are attached.

The tests made by the writer were made with a view to getting more information on the following points:—

1. To determine the effect on density and compressive strength due to variations in the mechanical analysis of aggregate greater than 1-10th maximum sized stone.
2. To compare a mix graded exactly to Fuller's rule to a mix with crusher run rock and sand sufficient to fill the voids, that is, a commercial mix.
3. To compare the ideal mix with mixes having the following variations:—
    - (*a*) Excess of medium sized stone.
    - (*b*) Excess of maximum sized stone.

Data for Plotting Curves of Ideal Mix from *Taylor & Thompson's Concrete Plain and Reinforced.*

Materials.	Intersection of Tangent with Vertical at Zero Diameter.	Height of Tangent Point.	Axes of Ellipses. a	$b+7$
Crushed stone and sand ..	28·5	37·7	0·150D	37·4
Gravel and stone	26·0	33·4	0·164D	35·6
Crushed stone and screenings	29·0	36·1	0·147D	37·8

The figures used in present test were those for "crushed stone and sand."

It is interesting to note that for these variations the graphs do not vary much.

To use this table for crushed stone and sand draw out a diagram on squared paper, showing "Effective sizes" on horizontal base and "Percentages passing" on vertical base.

Mark at zero diam. on vertical scale 28·5. Join this up to junction of 100 per cent. and 2-in. ring or max. size.

The two arms of the ellipse are:—

$$a = 0{\cdot}150\mathrm{D} = {\cdot}150 \times 2 \text{ in.} = {\cdot}30.$$

$$b + 7 = 37{\cdot}4, \text{ or } b = 30{\cdot}4.$$

Lay these values on the diagram and draw in the ellipse with horizontal axis 7 per cent. above zero and vertical axis 0·30 from zero.

In the present case the sand could not be made exactly ideal, which accounts for the difference in the lower part of the curve.

The "1-in. crusher run stone" was found to have a maximum size of 1·089, hence the curve goes up to that figure.

GENERAL PROCEDURE AND DATA.

The percentages of the aggregate were determined by the weight of dry material.

In all mixes 15 per cent. of cement was used in terms of the dry weight of aggregate (sand plus rock).

Sieves were all rated so as to determine for purposes of comparison the size of a sphere whose volume would be equal to the largest particles of stone that will pass the sieve in question.

The method employed to arrive at this value is to weigh a known number of the largest size particles that will pass, take the specific gravity of the material, and calculate the equivalent sphere.

The values below 30 mesh (square) were taken from previous determinations.

Table of Sizes of Sieves and Rating.

Nominal Size.	Diameter Passing.
2-in. circular	1·729 in.
1½in. ,,	1·300 in.
1¼-in. ,,	1·089 in.
1-in. ,,	·872 in.
¾-in. ,,	·665 in.
½-in. ,,	·451 in.
¼-in. ,,	·254 in.
6 mesh (square)	·156 in.
10 ,, ,,	·086 in.
16 ,, ,,	·047 in.
20 ,, ,,	·032 in.
30 ,, ,,	·023 in.
40 ,, ,,	·018 in.
60 ,, ,,	·011 in.
80 ,, ,,	·0061 in.
100 ,, ,,	·0059 in.
200 ,, ,,	·0036 in.

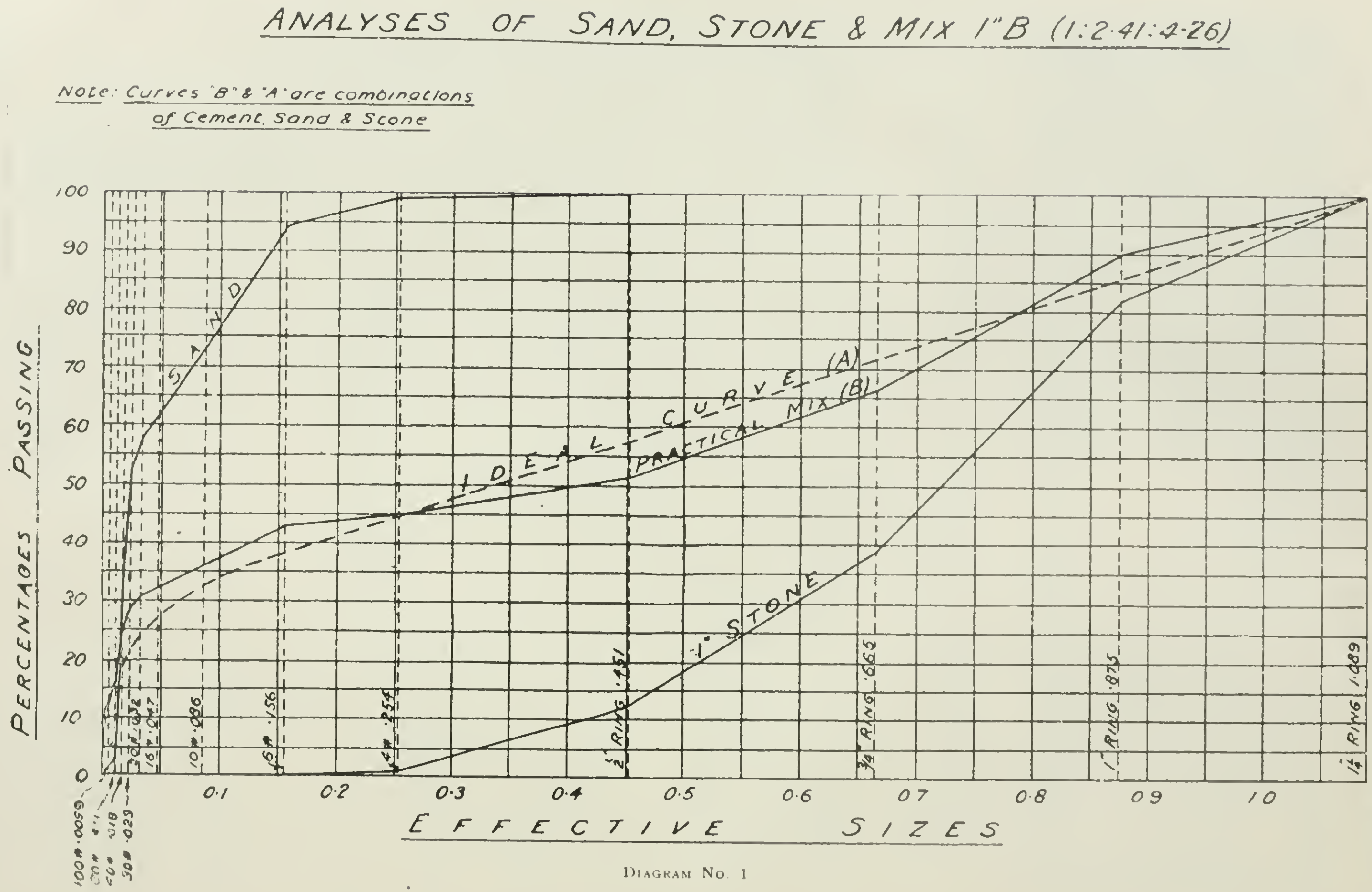

ANALYSES OF SAND, STONE & MIX 1"B (1:2·41:4·26)
Note: Curves "B" & "A" are combinations of Cement, Sand & Stone
PERCENTAGES PASSING
100
90
80
70
60
50
40
30
20
10
0
EFFECTIVE SIZES
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
100# ·0059
80# ·011
40# ·018
30# ·029
30# ·032
16# ·047
10# ·086
6# ·156
4# ·254
½" RING ·451
¾" RING ·665
1" RING ·875
1¼" RING 1·089
SAND
IDEAL CURVE (A)
PRACTICAL MIX (B)
1" STONE

Diagram No. 1

METHOD TO DETERMINE BEST PROPORTIONS BY MECHANICAL ANALYSIS.

MAKE A MECHANICAL ANALYSIS OF CEMENT, SAND, AND STONE TO BE USED.

The following are typical analyses of the materials used in the 2-in. practical mix in these tests :—

——	Cement.	Sand.	Stone.	1 : 2 : 4 mix.	1 : 1½ : 4½ mix.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
2-in.	100	100	100	100	100
1½-in.	100	100	61·6	77·9	75·3
1-in.	100	100	49·4	71·9	67·3
½-in.	100	100	9·4	48·1	41·7
4 mesh (sq.)	100	99·5	1·6	43·6	36·6
10 ,,	100	72·4	—	35·0	29·8
20 ,,	100	57·4	—	30·7	26·6
40 ,,	100	34	—	24·0	20·6

It is now necessary to determine the proportion of cement to aggregate by the class of work for which the concrete is to be used, such as 1 : 6. Then to determine the sand to stone, work out different combinations and try which most nearly fits the ideal curve for 2-in. stone and sand shown dotted in Diagram No. 3.

To arrive at the values for combined curve, work out as a first trial 1 : 2 : 4 concrete, that is :—

Cement, 14·3 per cent.
Sand, 28·6 per cent.
Stone, 57·1 per cent.

It is clear that these percentages multiplied by " the percentage passing " of each size particle added for any one size will give the value for the combined curve for that size; thus for 4 mesh (square).

Cement, 14·3 per cent. × 100 per cent. = 14·3 per cent.
Sand, 28·6 per cent. × 99·5 per cent. = 28·4 per cent.
Stone, 57·1 per cent. × 1·6 per cent. = ·9 per cent.

43·6 per cent.

Similarly for all other screen values which give results from which the new 1 : 2 : 4 curve is plotted.

It gives a curve rather above ideal, so 1 : 1½ : 4½ can be tried the same way, and gives a curve closer to the ideal with less sand, so getting a better concrete at slightly less cost.

The values for 1 : 2·24 : 4·45 are also given, as these were arrived at by measuring the voids in the stone and adding enough sand to a little more than fill them.

This does not give a very satisfactory mix; but, unfortunately, these tests do not go far enough to say what reduction of cement is possible to make the well-graded mix equal in strength to the mix with excess of sand; but they confirm the theory that compressive strength varies within ordinary limits as the density, and show that in the mixes tested a 22 per cent. excess of medium stone above the ideal result in 1 per cent. or 2 per cent. lower density, and, therefore, less strength.

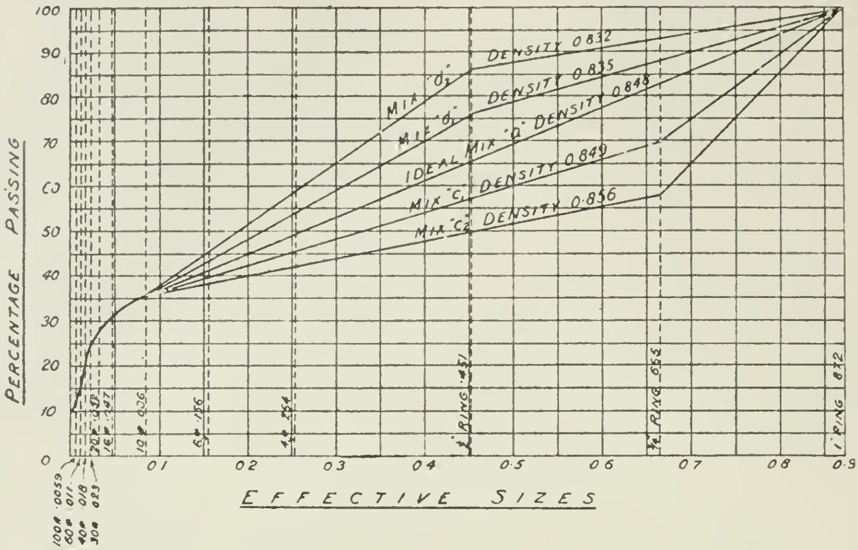
The above sounds complicated, but the figures can be arrived at in a few minutes with the aid of a slide rule, and the results give a very close idea of the class of concrete that will be produced without the delay experienced in the more usual method of making up and breaking test blocks.

Attention is drawn to Conclusion No. 6, which shows that a mix should never

ARTIFICIAL MIXES OF 1" MAX STONE

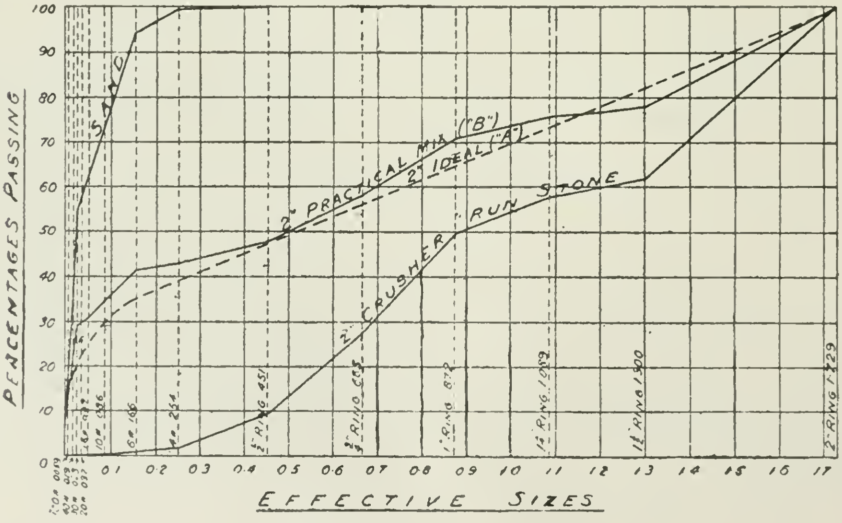
PROPORTIONS & DENSITIES

Note All curves are combinations of Cement, Sand & Stone



ANALYSES OF SAND, STONE & MIX 2"B (1:2.24 4.45)

Note: Curves "B" & "A" are combinations of Cement, Sand, & Stone



Diagrams Nos. 2 and 3.

err on the side of excess of medium sized material, and probably explains why some concrete, though to all appearances compact and good, does not come up to the strength expected.

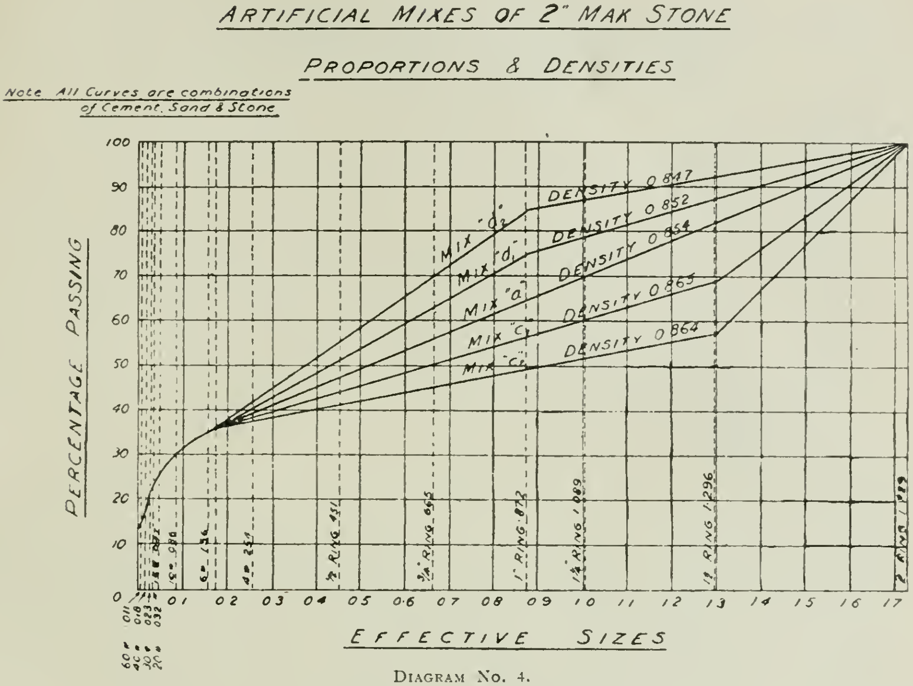


Diagram No. 4.

RESULTS OF THE TESTS.

The results are tabulated in Table 5 (see p. 554). The data used in the computations are as follows:—

Weights per Cu. Foot, Solid (No Voids).

Water,	62·4 lb. per cu. ft.
Cement,	193·44 lb. per cu. ft.
Sand,	157·90 lb. per cu. ft.
Stone,	167·54 lb. per cu. ft.

Weights per Cu. Ft., including Voids.

Sand,	86·60 lb. per cu. ft.
1-in. Crusher Run Stone,	83·85 lb. per cu. ft.
2-in. Crusher Run Stone,	93·00 lb. per cu. ft.

Specific Gravities.

Water,	1·000.
Cement,	3·100.
Sand,	2·530.
Stone,	2·685.

Proportioning Sand and Stone for Practical Mixes.—B.

Stone weight per cu. ft., loose, 83·85 lb.
Sand weight per cu. ft., loose, 86·60 lb.

RESULTS OF DENSITY AND COMPRESSION TESTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14		15	16	17	18	19	20
Reference Number	Mix	Weight of Materials as Set Lbs per Cub. Ft.				Calculated Weights of Materials as Set					Density		Compressive Strengths Lbs per Sq. In.						Remarks	Reference Number
		Water	Cement	Sand	Stone	Water	Cement	Sand	Stone	Total	Each Batch	Average	Age Day	No. of Breaks	Max.	Min	% Variation	Average		
2	1"B	9·797	17·679	44 586	78·916	0·1570	0·0914	0·2624	0 4710	1·0018	0·8448	0 843	90	4	5144	4627	10%	4890	Rather dry Proportion right	2
3	1"B	10·062	17·810	44·490	76 579	0·1612	0·0920	0·2817	0·4677	1·0026	0·8414		"	"	4980	4426	11 ·		Water right Good mix.	3
6	1"A	9·660	18·030	32 215	91·940	0·1548	0·0932	0 2040	0 5508	1 0028	0 8480	0 848	"	"	5358	4509	15 ·	5195	Too Dry Good Mix.	6
8	1"A	9·710	18·189	32 320	92·176	0·1556	0 0940	0·2047	0·5502	1 0045	0 8489		"	"	4960	4404	11 ··		Dry Smooth Working.	8
9	1"C$_1$	9·878	18 350	32·438	92·394	0 1583	0·0948	0 2054	0 5514	1·0099	0 8516	0 849	"	"	5015	4738	5 ·	4670	Dry very Good Mix	9
10	1"C$_1$	10·350	17·892	32·240	92·56	0·1658	0·0925	0·2041	0 5501	1 0125	0 8467		"	"	4640	4360	2 ·		Rather Wet Very Good Working	10
11	1"C$_2$	9·593	18·372	32 652	93 123	0·1537	0 0949	0 2068	0 5558	1 0132	0 8575	0 856	"	"	5113	4792	6 -	4710	Rather Rocky Works Rougher	11
12	1"C$_2$	9·701	18·321	32 570	92 880	0·1554	0·0947	0·2062	0·5544	1·0107	0·8553		"	"	4713	4146	12 -		Wetter than 11, otherwise the same.	12
13	1"d$_1$	10·288	17·880	31 814	90·759	0·1648	0 0924	0 2015	0·5417	1·0004	0·8356	0·835	"	"	4331	3436	21 ·	4195	Excess of fine Mat. Consistency Normal	13
14	1"d$_1$	10·910	17·701	31·776	90·762	0·1748	0·0915	0·2021	0·5417	1·0092	0 8344		"	"	4541	4202	7 ·		ditto	14
15	1"d$_2$	11·053	17·800	31 725	90·524	0·1771	0 0920	0·2009	0·5403	1 0103	0·8332	0·832	"	"	4258	3778	11 ·	3695	Excess of fine Mat. Rather Wet	15
16	1"d$_2$	10·487	17·745	31 641	90·299	0·1680	0·0917	0·2003	0·5389	0·9989	0·8309		"	"	3460	3014	13		ditto Too dry	16
4	2"B	9·794	17·931	41·602	83 306	0·1569	0·0926	0·2634	0·4972	1 0101	0 8532	0·852	"	"	5765	4304	22 ·	4760	Well proportioned & smooth working	4
5	2"B	9·640	17·990	41·511	83·084	0·1545	0·0930	0·2628	0·4959	1·0062	0·8517		"	"	5008	4174	16 ·		ditto slightly wetter than 4	5
27	2"A	9·912	18·189	31·561	93·620	0·1588	0·0940	0·1998	0·5568	1 0114	0 8526	0 854	"	"	4643	4005	14 ·	4450	Right Mixture handles slightly rough	27
18	2"A	9·571	18 119	31·622	93·860	0·1534	0 0936	0·2012	0 5602	1·0084	0 8550		"	"	4776	4447	7 ·		27&18 Good Consistency	18
19	2"C$_1$	9·138	18 515	32·064	95·092	0·1464	0·0957	0 2030	0·5676	1 0127	0 8663	0·865	"	"	5316	4949	7 ··	49:5	Rocky respecting large stone	19
20	2"C$_1$	9·506	18·433	31·961	94 758	0·1523	0·0953	0 2024	0·5655	1·0155	0·8632		"	"	5085	4612	9 ·		Excess Large Stone	20
21	2"C$_2$	9·312	18 522	31·984	94 843	0·1492	0 0957	0·2025	0·5661	1 0135	0·8643	0 864	"	"	5677	4722	17	5150	Large excess. Large Stone inclined to separate	21
22	2"C$_2$	9·151	18 487	31 982	94 843	0·1466	0 0956	0·2025	0 5661	1·0108	0·8642		"	"	5341	4826	10 ·		ditto	22
23	2"d$_1$	9·797	18 107	31 550	93·619	0 1570	0 0936	0·2008	0·5588	1·0102	0·8532	0·852	"	"	5789	5062	12 ··	4975	Excess fine difficult to work	23
24	2"d$_1$	9·714	18 140	31 476	93 370	0 1556	0 0937	0 1993	0 5573	1·0059	0·8503		"	"	4900	4050	17 ··		ditto	24
25	2"d$_2$	9·532	18·093	31·396	93·130	0·1527	0·0935	0 1988	0·5558	1 0008	0 8481	0 847	"	"	4763	4149	13	4460	Excess fine less marked than in d$_1$	25
26	2"d$_2$	10·218	18 057	31 319	92 890	0·1637	0·0933	0·1983	0 5544	1·0097	0·8460		"	"	4610	4198	9 ··		ditto	26

TABLE No. 5.

The voids were found to be 49 per cent. in the 1-in. stone, so, to follow the usual practice of allowing 5 per cent. surplus, 55 per cent. of sand to stone was allowed, as follows (including cement, 15 per cent. of sand and stone) :—

Stone,	27·95 lb. =	55·50 per cent.
Sand,	15·88 lb. =	31·46 per cent.
Cement,	6·58 lb. =	13·04 per cent.
	50·42 lb.	100·00 per cent.

For the 2-in. practical mix the voids in the stone were 43 per cent. and 48·5 per cent. of sand to stone was allowed, the cement, as before, being 15 per cent. of total sand and stone.

Stone,	27·95 lb. =	57·9 per cent.
Sand,	14·00 lb. =	29·06 per cent.
Cement,	6·29 lb. =	13·04 per cent.
	48·24 lb.	100·00 per cent.

MECHANICAL ANALYSIS OF MATERIALS USED IN PRACTICAL MIXES.

1-in. Crusher Run Stone.		2-in. Crusher Run Stone.		Sand.	
Passing :	Per cent.		Per cent.		Per cent.
1¼-in.	100	2-in.	100	½-in.	100
1-in.	82·24	1½-in.	61·6	4 mesh (sq.)	99·5
¾-in.	39·83	1¼-in.	57·7	6 ,,	94·41
½-in.	12·88	1-in.	49·4	10 ,,	72·46
4 mesh (sq.)	1·40	¾-in.	27·1	16 ,,	61·44
6 ,,	·40	½-in.	9·4	20 ,,	57·38
10 ,,	·20	4 mesh (sq.)	1·6	30 ,,	52·70
—	—	6 ,,	0·94	40 ,,	34·5
—	—	10 ,,	0·13	60 ,,	8·7
—	—	16 ,,	0·13	80 ,,	2·4
—	—	20 ,,	0·13	100 ,,	1·7
—	—	—	—	200 ,,	0·6

WEIGHTS OF MATERIALS USED IN THE TESTS.

Practical Mix 1-in. B.		Weight.	Practical Mix 2-in. B.		Weight.
	Per cent.			Per cent.	
1¼-in.	100	lbs. Cement .. 6·58 Sand .. 15·87 Stone .. 27·97 50·42 = 1 : 2·41 : 4·26	2-in.	100	lbs. Cement .. ·29 Sand .. 14·00 Stone .. 27·95 48·24 = 1 : 2·24 : 4·45
1-in.	90·1		1½-in.	77·7	
¾-in.	66·45		1¼-in.	75·4	
½-in.	51·49		1-in.	70·7	
4 mesh (sq.)	45·11		¾-in.	57·8	
6 ,,	43·01		½-in.	47·5	
10 ,,	35·95		4 mesh (sq.	42·86	
16 ,,	32·35		6 ,,	41·08	
20 ,,	31·09		10 ,,	34·21	
30 ,,	29·59		16 ,,	30·41	
40 ,,	23·84		20 ,,	29·81	
60 ,,	15·76		30 ,,	28·34	
80 ,,	13·79		40 ,,	23·04	
100 ,,	11·83		60 ,,	15·54	
200 ,,	11·48		80 ,,	13·86	
—	—		100 ,,	11·83	
—	—		200 ,,	11·50	

WEIGHTS OF MATERIALS USED IN THE TESTS WITH 1-IN STONE.

	Mix	1-in. *A*	Mix	1-in. *C1*	Mix	1-in. *C2*	Mix	1-in. *D1*	Mix	1-in. *D2*
1-in.	100%	lb.	100%	lb.	100%	lb.	100%	lb.	100%	lb.
		8·5		15·0		21·0		5·9		3·45
¾-in.	83		70		58		88·2		93·1	
		8·8		6·45		4·16		6·1		3·55
½-in.	65·4		57·1		49·7		76		86·0	
		8·05		5·75		3·76		10·95		13·6
Mesh (square)										
4	49·3		45·6		42·2		54·1		58·8	
		4·0		2·96		1·90		5·4		6·7
6	41·3		39·7		38·4		43·3		45·4	
		2·8		2·00		1·35		3·8		4·86
10	35·7		35·7		35·7		35·7		35·7	
		2·8		2·80		2·80		2·8		2·8
16	30·1		30·1		30·1		30·1		30·1	
		1·67		1·67		1·67		1·67		1·67
20	26·75		26·75		26·75		26·75		26·75	
		1·62		1·62		1·62		1·62		1·62
30	23·50		23·50		23·5		23·5		23·5	
40	19·92	0–30 Cement .. 6·52 „ Sand .. 5·23	19·92	0–30 Cement .. 6·52 „ Sand .. 5·23	19·92	0–30 Cement .. 6·52 „ Sand .. 5·23	19·92	0–30 Cement .. 6·52 „ Sand .. 5·23	19·92	0–30 Cement .. 6·52 „ Sand .. 5·23
60	14·78		14·78		14·78		14·78		14·78	
80	13·52		13·52		13·58		13·58		13·58	
100	11·65		11·65		11·65		11·65		11·65	
200	11·42		11·42		11·42		11·42		11·42	

WEIGHTS OF MATERIALS USED IN THE TESTS WITH 2-IN. STONE.

	Mix	2-in. *A*	Mix	2-in. *C1*	Mix	2-in. *C2*	Mix	2-in. *D1*	Mix	2-in. *D2*
2-in.	100%	lb. used	100%	lb. used	100%	lb. used	100%	lb. used	100%	lb. used
		8·9		15·5		21·5		6·35		3·8
1½-in.	82·2		69·0		57·0		87·3		92·4	
		4·25		3·1		1·9		3·05		1·85
1¼-in.	73·7		62·8		53·2		81·2		88·7	
		4·5		3·15		2·1		3·10		1·85
1-in.	64·7		56·5		49·0		75		85·0	
		4·25		3·05		2·0		5·8		7·25
¾-in.	56·2		50·4		45·0		63·4		70·5	
		4·5		3·2		2·0		6·0		7·5
½-in.	47·2		44·0		41·0		51·4		55·5	
		4·1		2·9		1·9		5·55		7·0
Mesh (square)										
4	39·0		38·2		37·2		40·3		41·5	
		2·0		1·6		1·1		2·65		3·25
6	35·0		35·0		35·0		35·0		35·0	
		2·75		2·75		2·75		2·75		2·75
10	29·5		29·5		29·5		29·5		29·5	
		2·5		2·5		2·5		2·5		2·5
16	24·5		24·5		24·5		24·5		24·5	
		1·4		1·4		1·4		1·4		1·4
20	21·7		21·7		21·7		21·7		21·7	
		1·1		1·1		1·1		1·1		1·1
30	19·5		19·5		19·5		19·5		19·5	
40	17·26	0–30 Cement .. 6·52 „ Sand .. 3·23	17·26	0–30 Cement .. 6·52 „ Sand .. 3·23	17·26	0–30 Cement .. 6·52 „ Sand .. 3·23	17·26	0–30 Cement .. 6·52 „ Sand .. 3·23	17·26	0–30 Cement .. 6·52 „ Sand .. 3·23
60	14·64		14·64		14·64		14·64		14·64	
80	13·33		13·33		13·33		13·33		13·33	
100	13·24		13·24		13·24		13·24		13·24	
200	13·13		13·13		13·13		13·13		13·13	

CONCLUSIONS.

1. The tests all go to show that the larger the maximum size of stone the greater the density. When the maximum sized stone is increased from 1 in. to 2 in., or 100 per cent., the density increase was an average of 1·5 per cent.

2. That mixes having large stone in excess of the ideal, that is mixes C_1 C_2 are slightly denser than that following the ideal curve exactly. Within the limits of these experiments, the greater the excess the greater the density. When the excess of stone between three-quarters maximum size and maximum size equalled 25 per cent., the increase in density was about 1 per cent.

3. That mixes having medium sized stone in excess of the ideal, that is mixes d_1 and d_2, have densities considerably lower than that of the ideal mix. In the 1-in. mixes an excess ot 22 per cent. in the medium sized stone shows a density 1·9 per cent. lower than the ideal, with the 2-in. stone the decrease is 0·8 per cent.

4. That the mixes having slight excess of large stone, C_1, are easier to work than either the ideal mix or the C_2 mix and much easier than the d mixes having an excess of medium stone.

The C_1 mixes, contrary to what was expected, produce cubes with a better surface than others and with much less labour.

When the large stone was further increased the large stones showed a tendency to get separated from the mortar; this was more noticeable in the case of the 2-in. mixes than the 1-in.

5. That generally the greater the density of concrete the greater the compressive strength; but that there is a mix following Fuller's rule, which has the greatest compressive strength without the greatest density. In the tests with 1-in. stone this is marked, but with the 2-in. stone the "ideal" mix is not the strongest; this, however, appears to be due to experimental error, as the C_1 mix is stronger than C_2, and the d_1 nearly as strong as the d_2, from which it would be expected that the intermediate or ideal mix would be at least equal to d_1 and C_1.

It follows from these conclusions that in proportioning aggregates which do not follow the ideal curve (and no practical mix can be expected to do so) it is important to keep the large stone in excess, or, in other words, to have the analysis curve below the ideal curve for the maximum sized stone in question. By following this rule the density of the concrete will be higher, the strength will be as great or greater, while at the same time the mixtures will work well, so long as the excess of large material is kept fairly low.

In the tests made the best results were obtained when the materials above three-quarters maximum size formed about 30 per cent. of the total.

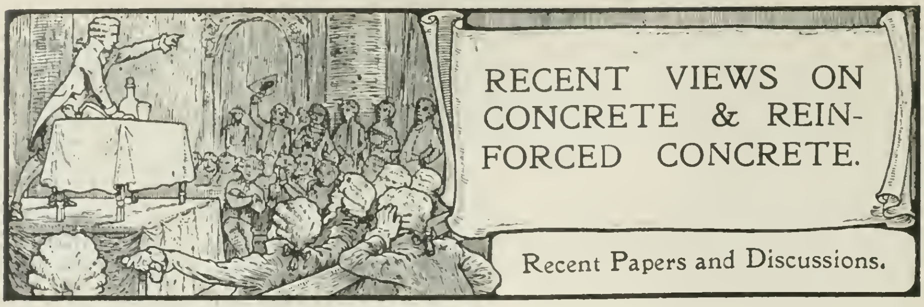
6. That there is a much greater falling off in compressive strength when the variation from the "ideal" is an excess of medium sized stone than when it is an excess of maximum sized stone. This is borne out by both series of tests.

The results with 2-in. stone are more irregular than with 1 in., due to using 4-in. cubes in both cases to get comparative results.

The cubes for the 2-in. mixes should be larger, so that the effect of one or two large stones is minimised. To keep the results comparative 6-in. cubes could be used in both series.

The writer wishes to acknowledge the help received from Professor Derleth and the staff of the Civil Engineering Department of the University of California, and particularly from Professor Alvarez, who acted as adviser and took a keen interest in the details of the work.

A similar series of tests with gravel aggregate are now being carried out at the University of California.



RECENT VIEWS ON CONCRETE & REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

NATIONAL CONFERENCE ON CONCRETE ROAD BUILDING.

CONCRETE HIGHWAYS SUBJECTED TO EXTREMES OF TEMPERATURE.

By H. S. VAN SCOYOC, A.M.Can.Soc.C.E., A.M.Am.Soc.C.E.

Chief Engineer The Toronto and Hamilton Highway Commission.

The following is one of the most important papers read at the National Conference on Concrete Road Building, held in Chicago in February this year, and published in the Proceedings of the Conference We also refer our readers to the review on the papers read at this Conference, the first part of which appeared in our September issue, and which is continued in the current number.

Since July, 1912, my work has been confined entirely to the Dominion of Canada, and my time has been given largely to problems arising in connection with concrete paving. The work has taken me into all of the provinces except British Columbia, and has afforded a good opportunity to observe pavements already laid, pavements under construction, and in some cases to observe these pavements year by year with knowledge of the quality of the materials used and the methods of construction followed. Temperature ranges of 120° Fahrenheit are not unusual, and in some cases the range is 150°. In some sections below-zero weather prevails for several weeks at a time, so that frost penetrates to a depth greater than in most parts of the United States. The effects of these conditions on concrete roadways can be discussed in three groups:—

1. A breaking up of the surface due to the mechanical effects of frost action.
2. Expansion and contraction due to temperature changes with the formation of transverse cracks.
3. The upheaval of slabs or parts of slabs, with the likelihood of longitudinal cracks occurring.

MECHANICAL FROST ACTION.

While it is possible that a porous concrete weak in cement might tend to break up on account of expansion caused by freezing, there is small likelihood of this trouble occurring if a satisfactory quality of concrete is secured. No actual case of this kind has ever come to my attention. This must not be confused with the damage that results when concrete is laid in freezing weather or is frozen before it has had sufficient time to set up properly. This is a real danger and is one difficult to remedy after it has taken place. In addition to rutting or picking up under traffic, concrete roadways laid in freezing weather may lack sufficient strength to withstand the stresses that the succeeding winter and spring induce.

EXPANSION AND CONTRACTION DUE TO TEMPERATURE CHANGES.

The first thought with regard to the effect of such ranges of temperature on expansion and contraction is that they would prove serious. When it is realised, however, that most paving is laid at a temperature usually not lower than 60° Fahrenheit, and that the temperature will rarely rise above 90°, the amount of expansion to be provided for on account of temperature change is not large during the first season after construction.

The drop in temperature in winter produces a contraction which to a considerable extent provides for expansion during the hot weather. Contraction is very evident during Canadian winters.

In 1914 the Canada Cement Co., Ltd., laid a concrete road about one half-mile in length at its Point Aux Trembles Plant, near Montreal. It was constructed to serve as an outlet for heavy traffic from the plant, but was to some extent an experimental road. About 1,000 ft. was one-course work reinforced, a second 1,000 ft. was two-course work reinforced, and the remaining section was standard one-course work without reinforcing. Hydrated lime equal to 10 per cent. of the cement by weight was added to about one-half of each section. In both of the reinforced sections an attempt was made to have the work continuous, special care being taken to have the new concrete bond with the work of the preceding day, the reinforcing in all cases overlapping.

For several weeks after the concrete was laid the weather was quite warm, and apparently all of the sections had bonded, for no transverse cracks were noticeable, although a close watch was kept from day to day. A sudden change in temperature (about 50°) occurred, and over-night a noticeable transverse crack appeared between successive days' work, except in one instance where less than 50 ft. of concrete had been laid during a day owing to a mixer breakdown.

During the winter some of these joints opened more than half an inch. Other instances could be cited showing very noticeable contraction. At present I cannot recall a single instance, however, where there has been creeping of one slab on the other or evidences of buckling where transverse joints one-quarter inch wide have been provided at intervals not greater than 35 ft. and have been properly maintained. While there is this very noted contraction, there has not been expansion to produce buckling.

It is during the winter and very early spring that the contraction is most marked, and there does not seem to be the lag due to moisture change that has been reported from localities further south.

While some transverse cracks are undoubtedly due to improper filling over pipe or box culverts, I believe that many of them represent carelessness in stopping work elsewhere than at a vertical joint. I believe in practically every case, especially under our own conditions, that if work is stopped for even the noon hour and a proper vertical joint is not made, sooner or later there is going to be a transverse crack occur at that joint.

HEAVING.

Concrete pavements in Canada have shown evidences of heaving. During the winter of 1913 a street at Steelton, Ontario, adjoining the Canadian "Soo," was raised by frost 2 in., by actual levels taken by the town engineer, U. D. Redfern. It returned to place with no damage except a longitudinal crack. In a street in Truro, Nova Scotia, laid in 1913, one slab rose about 2 in., as was shown by its elevation above the combined curb and gutter adjoining. It settled back into place in the spring without even developing a crack.

Station Street, Oakville, was paved in 1914. In a length of about a mile there is only one spot where cracks have developed, and there is known to have been an underground spring there that was not properly taken care of. This work is reinforced, and the crack has not opened to any noticeable extent. It has been given no repairs to date.

An exceptional spell of warm weather in January of this year took all of the frost out of the ground along the Toronto and Hamilton highway. The completed portion, about 17 miles in length, was carefully inspected. In only one spot had longitudinal cracks developed, and there only three slabs were affected. At this particular spot the side ditches were not taken down to their full depth until after the concrete had been laid. In digging the ditches quicksand was encountered, and it is now very evident that when the thaw saturated the ground there was a lateral movement of the sub-grade material into the open ditch on the north side of the road, leaving the slab on that side unsupported. It settled, and a longitudinal crack developed. The crack is noticeably lower on the north side than it is on the south side.

During the summers of 1911 and 1912 there were laid near Winnipeg, Manitoba, several miles of what has sometimes been spoken of as a concrete road. It was actually constructed as a base for an asphalt pavement, but in an endeavour to reduce the initial cost it was not covered. The mixture was about 1 : 3 : 6, and no transverse joints were provided. It was laid on the natural soil, gumbo, a very retentive clay, and was given only the attention that sub-base work usually gets. It developed transverse cracks approximately every 30 ft., and during the first winter developed a number of narrow longitudinal cracks. It received no maintenance. The second winter opened up the longitudinal joints until many of them were more than an inch wide. By another spring some of them looked like gullies. The construction methods very often are responsible for the results.

Less than a mile from this location there was laid in 1913 a road under much more satisfactory conditions, although it also was laid on the natural soil, and the drainage provided consisted of field tile placed only about 10 in. below the surface. This road went through the first winter with only about eight cracks in a length of 2¼ miles. The second winter, however, I believe, largely on account of defects in the drainage, there developed a much greater number of cracks, although the road is still in a satisfactory condition. The field drains were backfilled with the natural material, an impervious clay.

In the late summer of 1912 a portion of the King Edward highway passing through the village of Napierville, Quebec, was laid of concrete (being, more or less, an experiment) by the Department of Roads of the Province. The grading was carefully done by day labour by the Department of Roads, and was thoroughly rolled. The concrete work was carefully done by a conscientious contractor with many years' experience in concrete work. This road has passed through four winters. Four cracks have developed. They have been filled once each season, and the road is as good as when built, although it gets all the through traffic from Montreal to New York State, as well as the local traffic of the village. A portion of this road is macadam, which had to be resurfaced before it was two years old.

Other instances could be given of longitudinal cracks developing, but enough has been said to show that in some cases the trouble has been caused by settlement of the sub-grade near the edges of the concrete due to improper preparation of the sub-grade. Sometimes boggy spots beneath the concrete have not been properly drained; the system of drainage provided has not permanently kept the sub-grade dry. In practically every case mentioned there is sufficient evidence to show that lack of proper care rather than climatic conditions has led to cracks. Reinforcing has had a beneficial result in some cases at least, by adding sufficient tensile strength to prevent the formation of cracks. This has been evidenced, I think, in cases similar to the one I mentioned, where the slabs actually rose and settled back into place again without cracks developing.

Canadian climate does not prevent the building of successful concrete roads, but it does serve to emphasize the advisability of thorough drainage, the careful carrying out of proven methods of construction, and the absolute necessity for a maintenance system that takes care of defects as soon as they appear.

I would like to pay a little special attention to the fact that the cracks come, and very often come more frequently, in concrete that is laid late in the fall, when the temperature is such that the concrete does not get full strength. This was brought particularly to my attention when we were making test cubes and subjecting them to the same curing process that the highway itself was getting. These were made throughout the entire construction season, in many cases of the same natural aggregate, the same mix, by the same gangs. It is remarkable the difference in strength that we would find at the end of the same test period with the compression cubes made on the road during the warmer weather and the cubes made late in the season. In one particular case on a stretch of 17 miles of concrete road there are seven cracks at the present time, and one only of the seven occurred in concrete laid prior to the 1st November.

Where I said, "The drop in temperature in winter produces a contraction which, to a considerable extent, provides for expansion during the hot weather," that would be contingent on our using such a joint material that it would provide for closing up in winter and expanding in summer again; or it means preventing the getting of materials into the joints that would prevent the proper expansion and contraction.

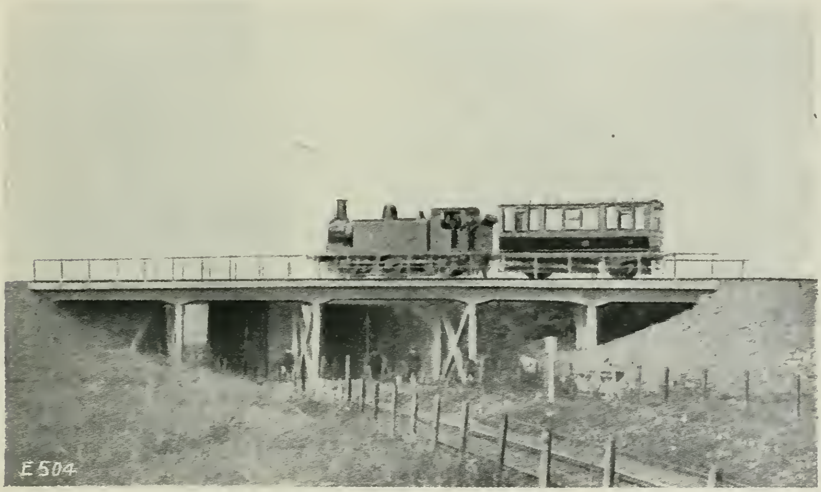
NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

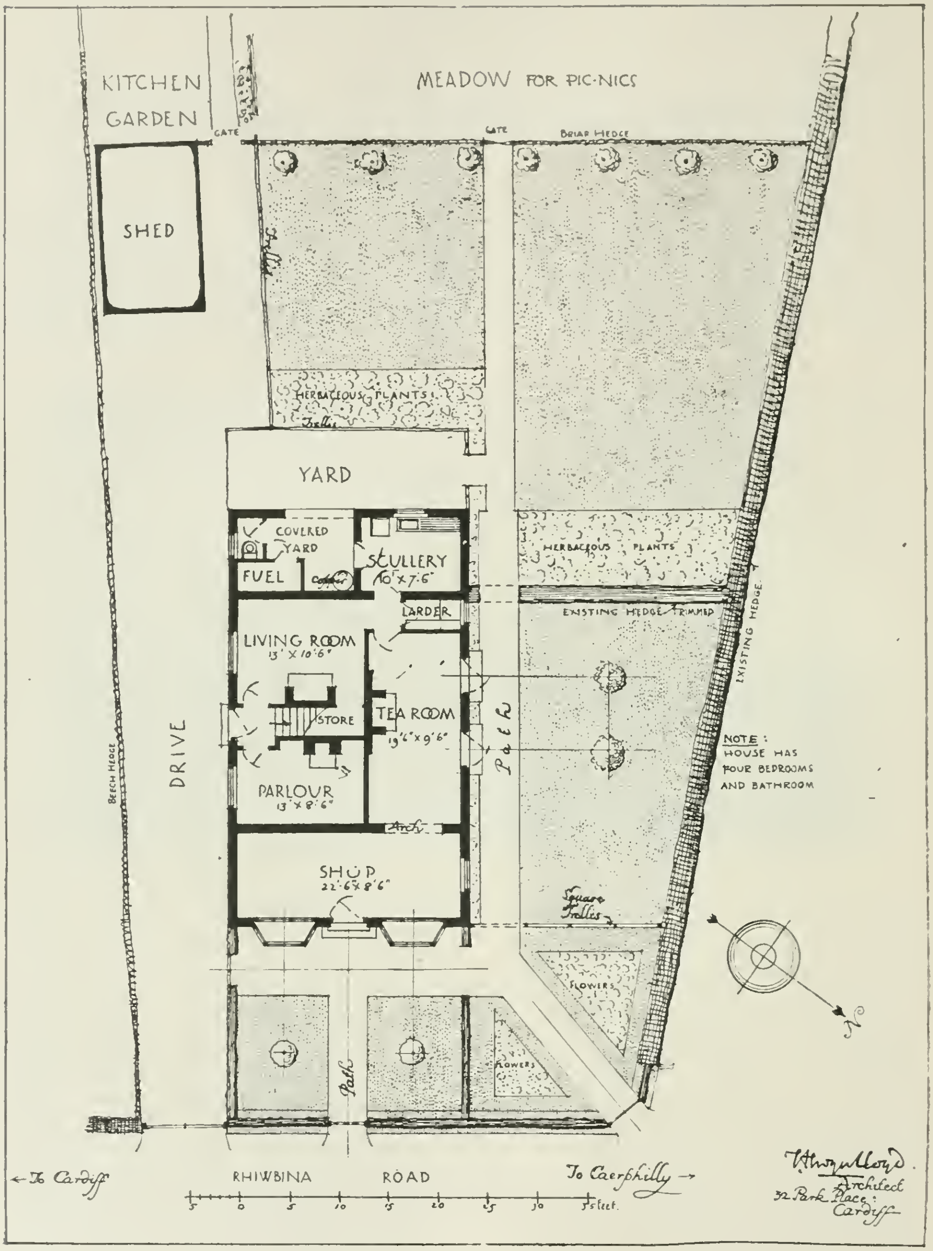
A REINFORCED CONCRETE RAILWAY BRIDGE IN AYRSHIRE.

A REINFORCED concrete railway bridge has just been completed in Scotland, on the Lanarkshire and Ayrshire Railway Company's route at Stevenston, and is a good type of a colliery railway bridge. The system adopted is the Considère system of reinforced concrete, and the bridge is designed to carry the heaviest goods locomotives of the Caledonian Railway Co. It consists of five skew spans. The work of construction involved bridging over a siding to explosives works, which had to be kept open for traffic, and an existing siding to the Ardeer Colliery pits from the Glasgow and South-Western Railway.

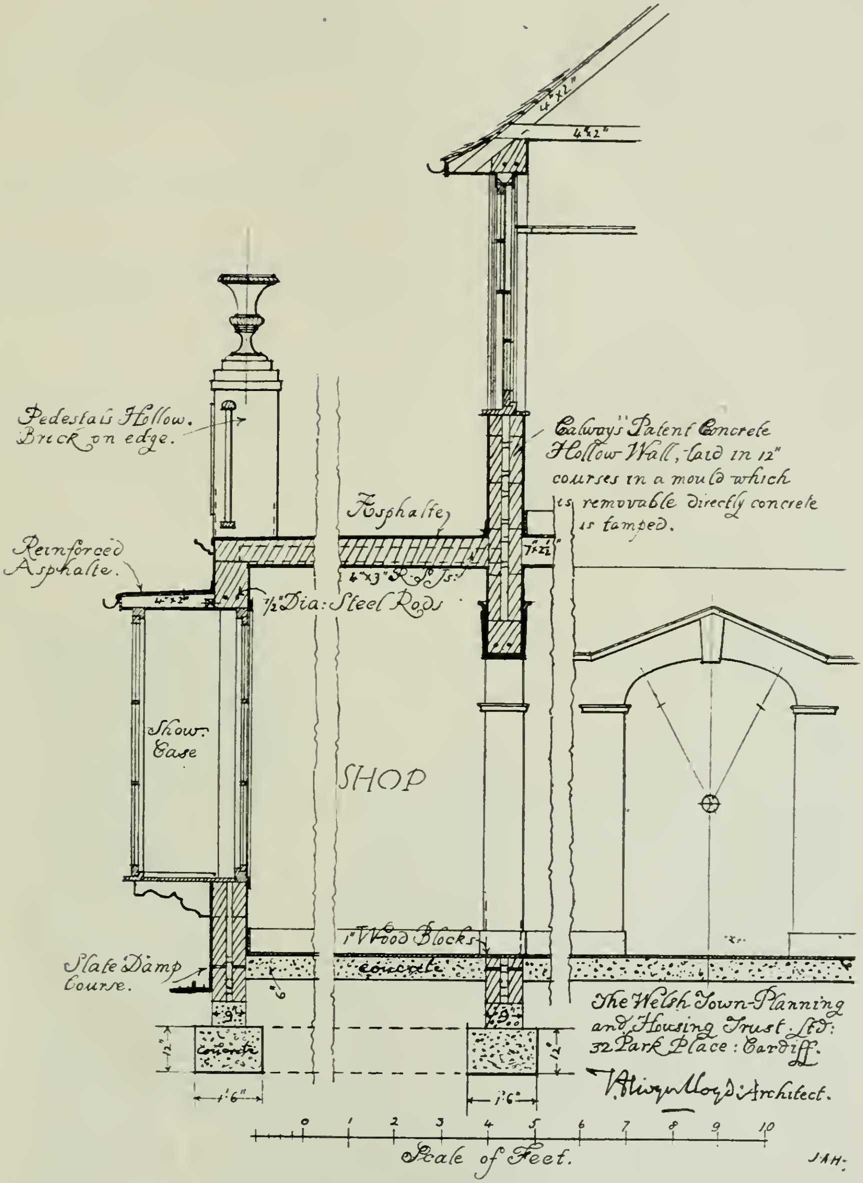


A REINFORCED CONCRETE COLLIERY RAILWAY BRIDGE.

This new bridge is for colliery purposes, has been thoroughly tested, and has given the utmost satisfaction. The contractors had very limited headroom, only 5 ft. clearance to work on below the underside of the main beams. The bridge is on a curve of 390 ft. radius, and crosses the existing sidings on a heavy skew. It is also on a gradient. The type of construction adopted is that of two main longitudinal beams 7 ft. apart, carrying a platform 16 ft. wide over all, the platform having an upstand at the outer edges 12 in. high and 6 in. wide to retain the ballast, and also to carry an iron hand-rail extending the full length of the bridge. The beams are carried on braced piers, consisting of columns directly under the main girders, with diagonal stiffening bracing, and resting on foundations 3 in. wide and 18 in. deep. The columns are 13 in. by 13 in., with a big chamfer, and are tied at the top by cross girders at each pier 1 ft. 11 in. deep and 13 in. wide. The cross bracing, square in section, is 9 in. by 9 in.; the platform on the top is 7 in. deep between the longitudinal girders, and tapering to 6 in. depth at the outer edge. The main girders are 1 ft. 9 in. deep, 13 in. wide throughout, with gussets at the columns, and altogether the bridge has a very light appearance.



RHIWBINA TEA-ROOMS, NEAR CARDIFF.


4"×2"
4"×2"
Pedestals Hollow. Brick on edge.
Calway's Patent Concrete Hollow Wall, laid in 12" courses in a mould which is removable directly concrete is tamped.
Asphalte
Reinforced Asphalte.
4"×2"
7"×2½"
4"×3" R.S.Js.
½" Dia: Steel Rods
Show Case
SHOP
1" Wood Blocks
concrete
Slate Damp Course.
6"
9"
9"
12"
concrete
12"
1'6"
1'6"
The Welsh Town-Planning and Housing Trust Ltd: 32 Park Place: Cardiff.
T. Alwyn Lloyd: Architect.
0 1 2 3 4 5 6 7 8 9 10
Scale of Feet.
J.A.H.

RHIWBINA TEA-ROOMS, NEAR CARDIFF.

In the construction, temporary wood trestles were erected at each pier, and steel joists laid on the top, spanning the existing sidings, and placed outside and close to the main longitudinal girders. The timber supporting the underside of the beams was then placed across, resting on the bottom of the flanges. From this working staging the whole bridge was constructed.

Messrs. Melville Dundas and Whitson, West George Street, Glasgow, were concontractors for the work; and Messrs. Formans and McCall, M.Inst.C.E., Hope Street, Glasgow, had the engineering planning under their care, and decided, after survey, to adopt a reinforced concrete structure.

RHIWBINA TEA-GARDENS.

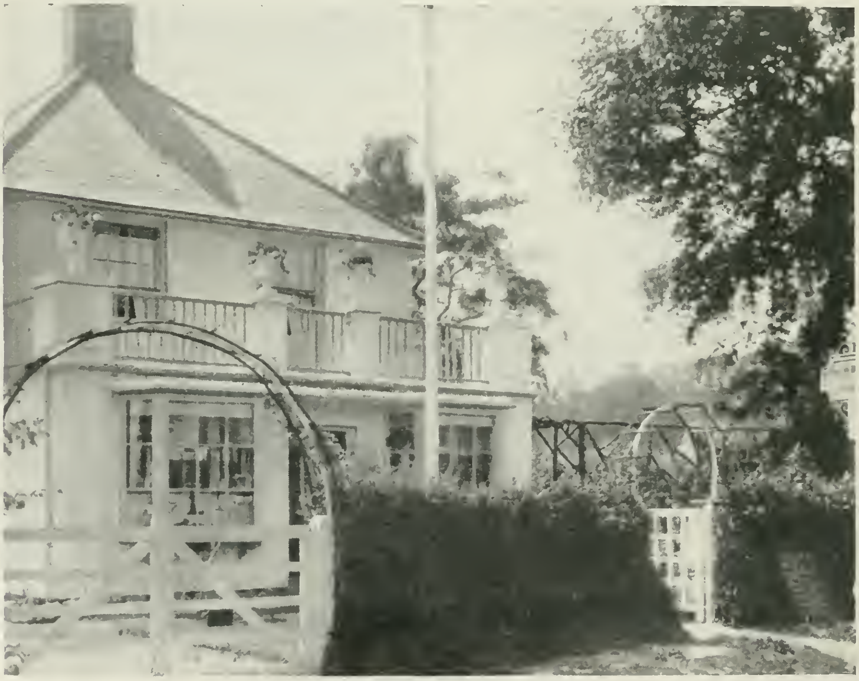
Rhiwbina is an old village near Cardiff. A garden village of 70 houses has been laid out, and a large scheme for the extension has been prepared by the Welsh Town-Planning and Housing Trust, Ltd., of Cardiff.

The Tea Gardens have been built in such a position that they will form part of the complete scheme of the Garden Village, and were designed by Mr. T. Alwyn Lloyd, Licentiate R.I.B.A., the architect to the Welsh Town-Planning and Housing Trust, Ltd.

The buildings were completed at the end of last year, and are constructed on the "Calway" patent system of concrete walling, 9 in. thick with 2 in. space. The walls are of fine concrete, composed of clinker, crushed stone and cement, in 12-in. courses, rammed into a mould which is pulled off and moved forward directly the cement has been well tamped. The walls were covered with two coats of cement rendering left rough from the float and colour washed. The accommodation is shown on the plan; the first floor has four bedrooms and a bathroom. The design was kept quite simple, and the roof was covered with blue-grey Welsh slates.

The garden was laid out by the proprietor, Mr. W. A. Smart, who departed from the plans in execution.

Mr. J. O. West, of Whitchurch, near Cardiff, was the builder.



Rhiwbina Tea-Rooms, near Cardiff.

NEW BOOKS

AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

The Theory and Practice of Modern Framed Structures. By the late J. B. Johnson, C.E., C. W. Bryan, C.E., and F. E. Turneaure, C.E.

London: Chapman & Hall, Ltd. New York: John Wiley & Sons, Ltd. Price 17/- net.

This book is the final volume of "Modern Framed Structures," which has been lately re-written and brought up to date in accordance with modern practice.

The greater portion of the volume deals with bridge design, but space is found for consideration of roof trusses; and many matters that are at present controversial are considered from an impartial point of view.

The determining conditions in the choice of the type of bridge required for any purpose are fully discussed in the first chapter. Following this the next five chapters deal with the various stresses, etc., that occur in steel structures, and a comparison of the formulæ used by different schools of engineers. These chapters are most comprehensive, and matters such as, for instance, eccentric rivet connections, are dealt with in a simple and masterly manner; and the engineer who has digested this section has no need to fear any problem that may occur in general practice.

After this introduction (which occupies more than 130 pages), the authors devote a section to each type of bridge; whilst the final chapter deals with the design of steel roof trusses.

Two of the three appendices included in the volume are of more value to American than to English readers, dealing as they do with American specifications and standards for structural work; but the third, dealing with unsymmetrical bending, will delight the engineer who revels in mathematical problems.

The work is very fully illustrated with diagrams and details, and a feature is the series of large folding plates showing different types of structures drawn as working drawings, and bound with the book in a manner that allows them to be referred to whilst the reader follows the text.

Before its re-writing, the work was widely known and in general use among engineers; and in its present form it deserves a place on the shelves of both the student and the busy engineer who wishes to keep abreast of his profession.

The Fire at the Edison Phonograph Works, New Jersey, U.S.A., of December, 1914. Red Book No. 204 of the British Fire Prevention Committee, by F. J. T. Stewart.

Published at 8 Waterloo Place, S.W. Price 3/6.

The British Fire Prevention Committee have just issued a report on the important fire at the Edison Phonograph Works in New Jersey, U.S.A., to which we have referred in an earlier issue (p. 401) The importance of the report on this fire to engineers and architects lies in the fact that the buildings were of reinforced concrete, and this is the first time that a fire of great severity and wide area in a building constructed of reinforced concrete has been under careful technical observation. The fire was not only a very serious one, but very intense; and whilst all other forms of construction and contents became a heap of ruins, the concrete buildings remained, with the exception of a comparatively small section, and could be reinstated in a remarkably short time.

The report issued by the British Fire Prevention Committee, which is from the pen of Mr. F. J. T. Stewart, chairman of the committee's allied organisation in the United States, describes the course of the fire, gives a detailed description of the damage done, the effect of the fire on the material, the temperatures developed, the conclusions arrived at, and some notes on the reconstruction. Seeing that the structures under review were erected as far back as 1905, when the modern practice of reinforced concrete was not yet existent, the showing is certainly remarkable. Amongst the lessons learned, however, is that of the necessity that even in this class of construction the buildings should be divided up in fire-tight compartments, and the exposure risk provided against by suitable sashes and fire-resisting glazing. Had such safeguards been provided for the limitation of the extent of this fire, the outbreak should have been readily confined to within reasonable limits.

The "Red Book" of the British Fire Prevention Committee is profusely illustrated with some twenty photographs, and also with two plans and certain diagrams.

MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

Concrete for Munition Factory.—A new munition factory is to be erected near London. The building has to be of a permanent character and of reasonably cheap construction. There is to be a factory with a machine shop at rear. There is also to be a metal store and a testing shop. The construction of the main or office building is to be of concrete blocks and brick walls, concrete floors as well as roofs and slab partitions. The factory is to have concrete walls and steel stanchions. The approximate estimated cost is £6,500. The architect is Mr. Arthur T. Davies, of Marsden Road, East Dulwich. —*Building News.*

Concrete Ships.—A reinforced concrete barge recently constructed in Sweden has just made a voyage from Moss to Christianiaford. It is proposed to construct other concrete ships in Sweden, from 15,000 to 20,000 tons displacement, to be used as railway ferries between Göteburg and England. Mr. Nicolai Fougnier, the engineer, is at present building a lighter for a mining company for the oversea export of iron ore and the import of coal.

Buildings in Chile.—Reporting on the openings for trade in the territory of Magallanes, H.M. Consul states that the buildings are mostly wood covered with corrugated iron roofs. The constant tendency, however, is towards greater solidity of construction. When not of wood, the buildings are generally of brick or reinforced concrete.

Irrigation Works in South Africa.—The Minister of Lands has reported on the development of irrigation works. The Calitzdorp Dam, in Oudtshoorn, is being constructed of concrete. It will be 113 ft. high, and will cost £120,000.

Reinforced Concrete Warehouse.—A large store has recently been opened at Scarborough. The building has been erected for Messrs. Boyes and Co., Ltd., and is of reinforced concrete throughout. The architect was Mr. J. Caleb Petch, and the general contractor was Mr. F. K. Plaxton, both of Scarborough. Steel stanchions are employed in the framework of the building, which comprises basement and three floors, having a total area of 38,380 sup. ft. Expanded steel, supplied by the Expanded Metal Co., West Hartlepool, was used for the reinforcement.

Cement Tile for Roofing.—Cement tile has been extensively used for roofing the new Chicago plant of the Crane Co. The roofs aggregate about 1,000,000 sq. ft., and different kinds of tile are used to meet the varying requirements of the different buildings.

Shanghai.—The expansion of the department-store business at Hongkong has been followed by similar plans at Shanghai. The latter city is to have an establishment on the scale of the mammoth Sincere Co. store at Hongkong, and it will be under the control of the same company. The new building will be larger than the Hongkong structure, and in addition to the store the Sincere Co. also intends to erect a hotel as an annex. The shop, which will be composed of reinforced concrete, will have a frontage of 100 by 150 ft., and will be a four-storey structure, divided into many rooms and departments. There will also be a roof garden, with plants, etc. Two lifts are also to be erected in the building for the convenience of customers. The hotel, adjoining the stores, will be a five-storey building, also of reinforced concrete, provided with two lifts.

A Peculiar Reinforced Concrete Rain-water Pipe.—In the town of Ann Arbor, in Michigan, a somewhat peculiar rain-water pipe has been constructed of reinforced concrete. It is right-angular, with inside dimensions 5 ft. by 5 ft., and is so bedded in the ground that its surface, without any cover or coating, serves as a pavement. The bottom of the pipe has a uniform fall of 3 in 100. The variations in height at crossings and in the fall of the surface are met by varying the height of the side walls.

Battery-Room Floors.—The construction of battery-room floors has been carefully studied by the New York Edison Company. Briefly, the floors are made impervious to acid by a covering and are graded so that they will drain toward one side, where a gutter is provided which empties into a lime box. The latter is employed to neutralise any acidified water which may be collected before it is discharged into the sewer.

The acid-proof coverings are laid on ordinary concrete floors reinforced by steel girders. Over this a 1 : 2 : 4 mixture of concrete with a cement-mortar finish is placed. The surface is then painted with hot "Hydrex" compound, and covered with three layers of butt-jointed acid-proof Hydrex felt, the strips being run with the flow line of the room. The joints are bonded with hot compound. Around the borders and under the drain box additional layers of felt and compound are employed. A second layer of 1 : 2 : 4 concrete is placed over all, finished and painted like the first, and covered with two crossed layers of acid-proof felt. Laid on this with their longest dimensions in the direction of the flow line of the room are 8 in. by 4 in. by 2·25 in. vitrified bricks, the spaces between which are filled with 0·25 in. rope separators and hot compound. The thickness of the first layer of concrete is tapered from the gutter to the opposite side of the floor to give the finished floor an 0·8 per cent. grade. The gutter in turn is given a 0·5 per cent. grade. The minimum thickness of the floor is made about 9⅛ in.

Where the acid-proof covering must pass over girders they are first covered with neat cement and a sheet of lead. Around the edges of the floors for the battery rooms are built low barriers of vitrified brick coated with acid-proof paint and separated from the walls by Hydrex felt and hot compound.

Possible Industries in Rhodesia.—In a letter written by Mr. P. N. Taylor, of the Rhodesian Munitions Committee, the following paragraph appears:—

"Another important point under consideration is cement and its uses. The particular lines at present being investigated are: Reinforced concrete tanks as a substitute for steel tanks, reinforced concrete pipes, and generally the possibilities of its application in structures and buildings as an efficient and economical substitute for imported articles."

Concrete Pipes for Drainage Work.—Among the first land to be irrigated by the Mormons, some twenty-six years ago in Utah, was an area lying about thirty-five miles north-west of Ogden and bordering on Great Salt. As happens in the arid regions where irrigation is necessary to carry on agriculture, this land has become so waterlogged that to restore it to its original productiveness drainage became necessary.

With this object in view, the Corinne, Utah, Drainage District was organised and bonds voted to the extent of $175,000 to raise the necessary funds to reclaim these lands. After due consideration, the sponsors of this drainage district have been converted to the use of concrete pipe for the development of this region, which will require something over 200 miles of pipe. The quantity of cement that will be utilised in this particular work will range from 8,000 to 10,000 barrels, which is not so large an amount as one would naturally expect, simply because few pipe of large diameter are necessary in the development.

W. M. Bostaph, a prominent civil engineer of Salt Lake, has been selected as chief engineer of this work, which will result in 200,000 acres of land being restored to profitable production.

A cement products plant, especially to provide the pipe necessary for this reclamation, will be erected at Corinne at a cost of $30,000.

Luton Railway Bridge.—The whole of the work in connection with this bridge (to which we referred last month) was carried out by the Yorkshire Hennebique Contracting Co., Ltd., of Leeds, and the reinforced concrete work was done on the Hennebique system.

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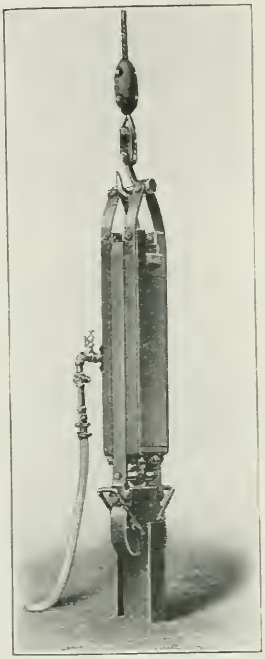
THE BRITISH STEEL PILING CO



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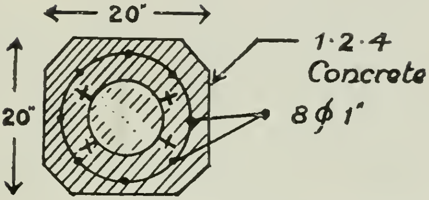
DOCK HOUSE, Billiter Street, LONDON E.C.

An Old Metal Viaduct strengthened with Reinforced Concrete.—Below we give an illustration of a viaduct on the Chile State Railway which has been strengthened with reinforced concrete and by adding a third girder. The concrete used was a 1 : 2 : 4 concrete, and the interior of the column was filled with a 1 : 3 mortar. The engineer, Mr. St. O. Tegeda Lawrence, who has sent us this photograph, informs us that the work was planned and constructed from ideas gathered in our journal.



The Construction of a Brewery.—In an article under this title in the *Journal of the Society of Architects*, Mr. J. Beardmore states: "The floors need particular thought and attention, and should be extremely rigid, solid, and hard. Concrete with a granolithic finished surface is preferable, as being jointless, although in some rooms, such as the malt loft, there may be a chilliness which is not desirable, and here a boarded floor may be adopted, also in the offices and hay and straw lofts. Even for the heaviest traffic a concrete floor composed of ½ clean sharp sand, 1½ suitable broken material, and 1 of best Portland cement will suffice if properly compounded."

CORRESPONDENCE.

British and American Measures.

To the Editor of Concrete and Constructional Engineering.

Sir,—As interesting to British engineering and commercial interests, would it not be well to remind your readers from time to time that the United States of America avoirdupois measure of one ton, when quoted simply as a ton and not specifically as "a ton of 2,240 pounds," is a ton of 2,000 lbs. only?

Also that the United States gallon is a wine measure gallon, having a cubic capacity of 231 in. only, against the British cubic capacity of 277·463 in. per gallon.

In commercial affairs, when quotations are received *abroad* from a British and an American house, each quoting per ton, or giving, say, the capacity of a pump at so many gallons, the foreigner is unconsciously (so far as he is concerned) often deceived into placing his order with the United States on account of the apparently cheaper tonnage price or the apparently greater pumping capacity.

From wide personal knowledge obtained whilst touring foreign countries, the writer knows that this point deserves more consideration than it generally receives in

Great Britain. Therefore, if you are in agreement as to the desirability of bringing these points to prominent notice occasionally, perhaps the publication of this letter will serve that purpose at present.

Yours faithfully,
C. T. Evennette.

PUBLICATIONS RECEIVED.

We have received two interesting publications issued by the General Fireproof Building Products Co., of 7, Ward Road, Dundee, dealing with the question of rendering structures of every kind fire-resisting by the aid of the Special Herringbone Rigid Metal Lath, which can be applied equally well to the external walls of wood frame structures as for reinforcement in concrete buildings, or, as a matter of fact, to buildings of every description. Self-Sentering or Trussit and cement plaster make good inside partitions, and at the same time it is claimed that its use means a saving of space and expense. It is claimed that buildings are rendered fire-resisting from without by the application of the material to external walls, whilst its use on internal walls, for floors and for ceilings will effectually prevent the spread of fire from one room to another.

Both booklets contain excellent reproductions of various buildings where this special product has been used.

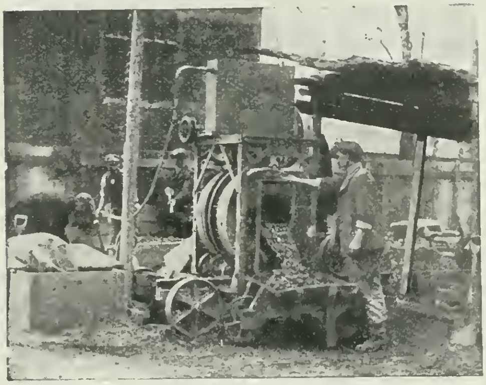
ERRATUM.

In our article on Water Towers last month we inadvertently gave the name of the architects of the Warrington tower wrongly. This should have read : " Messrs. William and Segar Owen," and in referring to the reinforcement used for the first three water towers it should have been described as the " B. R. C. system of reinforcement," instead of " B. R. C. Fabric."

PROPOSED NEW WORKS.

New Zealand.—The Wanganui Harbour Board has decided to complete a deep-water harbour scheme which will enable the berthage of eight liners inside the river mouth. Plans prepared by the Board's engineer have been approved. The Dunedin Corporation intend to ask for authority to borrow £140,000 for a water scheme.

Russia.—An issue of 6,882,000 roubles from the Russian Treasury in 1916 has been authorised for expenditure on port improvement works.



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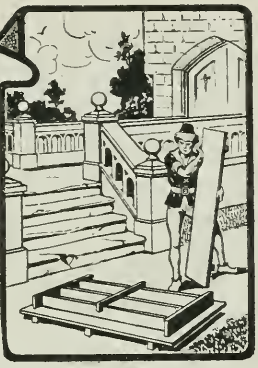


CONCRETE BLOCKS AND HOW TO MAKE THEM.

In the following articles (which have been specially contributed), it is intended to give instructions of how to make the concrete blocks. The machinery, moulds, etc., are referred to only in a general way, as we have already illustrated and described from time to time the principal types of block-making machines, etc., that are on the market in this country.—ED.

CONCRETE is becoming more of an everyday building material in one form or another, and when the war is over everyone will be on the alert for a good, substantial, and, above all, cheap material, and no doubt the concrete block will play a great part, especially for small houses, cottages, farm buildings, etc.

It has been stated time after time that it requires a skilled man to make satisfactory blocks, but the writer has proved to his own satisfaction that all it requires is a good, reliable man in charge of the men who are set upon the job to make the blocks. The particulars given in this and succeeding numbers are intended to enable any builder to instruct a good, handy labourer in the way to make blocks, and it is proposed to deal with the different stages under the various headings, taking, first of all, aggregates and then cement, etc.

Aggregates.—There are many different materials suitable as aggregate for use with Portland cement, and practically any hard and clean material can be used.

1. Ballast.
2. Broken stone.
3. Crushed granite.
4. Broken brick.
5. Burnt ballast.
6. Coke breeze.
7. Pumice.
8. Clinker.

Ballast forms a concrete that has great strength as regards crushing strains. It should be freed from all dirt and loam. River ballast, as a rule, is very free from dirt and loam, but if obtained from pits it is more liable to be dirty and to contain impurities which are detrimental to strong concrete. In some cases, where the ballast is obtained from pits, the particles are coated with loam or clay, and unless these particles are cleansed from this impurity it will be found that the resultant concrete is very weak.

The reason why poor concrete is obtained when the presence of loam or clay abounds is because the loam or clay which surrounds the particles stops the cement from joining the particles together in the crystallisation which takes place, or, to describe it more practically, the loam prevents the adhesion of the cement to the particles of sand and stone, and unless the adhesion can take place the concrete will be weak.

Crushed Ballast will produce concrete of a stronger nature than ballast straight from the river, as, owing to the action of the water, the river ballast has less sharp edges. Thus the crushed ballast, being more angular and irregular in shape, makes by far the stronger concrete.

The size of aggregates for concrete blocks, fencing posts, window sills, etc., etc., should be from ½ in. downward, but must be free from dust, as dust reduces the action of the cement and weakens the concrete. Ballast is more often used on large floors, etc., than in concrete block making.

Broken Stone.—Hard limestone will form good and strong concrete if crushed to the required size and freed from dust, which reduces the strength of the concrete. Limestone cannot be called fire-resisting, as, when heated to high temperature, calcination takes place. If the limestone is broken small, this does not affect it much, as fire will not penetrate far into concrete.

Crushed Granite.—This is one of the very best aggregates for all kinds of concrete work, especially for domestic concrete work, such as doorsteps, floors, paving slabs, thin window-sills, etc., etc. Care must be taken that when the granite is fine no dust be in it. For concrete block work it should be crushed from $\frac{3}{8}$ in. downward and gauged with sand. It makes a very strong and good block.

Broken Brick.—This is another good aggregate, and is fire-resisting, and if crushed to the required size and freed from dust makes an excellent concrete. But it has other drawbacks, as it is not possible to know where the bricks have been used, and the plastering upon the bricks may set up a chemical action and destroy the setting qualities of the cement. For instance, it has been known, where brickwork has been taken down and used for concrete work, that the bricks were plastered with sulphate of lime in the form of plaster, and when this gets into the concrete disintegration takes place. Again, old bricks have been known to have been plastered with Keene's cement, and when the Keene's comes in contact with Portland cement and water a chemical action takes place and causes it to increase in volume. It may only be slight, but, on the other hand, it may be considerable, according to the amount of water used. Yet if a batch of concrete made with crushed bricks which had been plastered with Keene's cement were used half in a dry situation and the remainder in a constantly damp place, the dry might not show any signs of disintegration, but the part in the damp locality would be absolutely useless. Thus it will be seen that it is best not to use broken bricks for aggregate. Some bricks contain sulphur in themselves, and thus are useless for concrete work of any kind, as this will cause disintegration.

Burnt Ballast.—This is not a good material for aggregate, and it is best not to use it unless absolutely forced to do so by circumstances. A good many of the remarks on broken bricks apply here.

Coke Breeze.—This is an excellent material as aggregate where porosity does not matter and is not objectionable. Coke breeze must not be confused with what is commonly called "breeze", as coke breeze is composed of very small pieces of coke and is rather expensive. Coke breeze should not be dusty, and should be free from sulphur, ammonia, and organic impurities. Scotch coal generally contains an excess of sulphur, and should be avoided. In many cases pan breeze is sold for coke breeze, and failures have been traced to pan breeze, as it often contains an excess of sulphur, and when the cement comes in contact with the breeze, the lime in the cement and the sulphur in the breeze combine together and form sulphate of lime.

Pumice is one of the best aggregates for concrete work that can be obtained. It has all the good points that were explained in the preceding paragraph on coke breeze, but at the same time does not possess the drawbacks, such as sulphur and ammonia, which are common in breeze, and thus it is more reliable, or can be said to be absolutely reliable for concrete work. It has one disadvantage, and that is its porosity, but this may be overcome to a certain extent, which will be explained later. It is very light but is rather expensive.

Clinker.—Care should be taken when selecting clinker for use as an aggregate, as it contains (very often) large quantities of sulphur and not thoroughly burnt coal, etc., but when possible to select good clinker it is a first-class aggregate. On no account is it advisable to use ashes or clinker from a refuse destructor works, for failure is sure to result. It contains large quantities of unburnt house refuse and broken glass and crockery, which all have a bad and disintegrating effect on concrete.

Cement for the manufacture of concrete goods must be an absolutely first-class article, for not only does the finished article depend on the aggregate, but it also depends a very great deal upon the cement. When ordering cement it is always best to specify that it is to be "the best English Portland cement" ground to the British engineering specification. This will ensure a first-class article, but it is always best to make a few tests to satisfy yourself and also to ensure that you are getting a good article. Before the war, cement was imported from abroad and packed in bags and marked "Portland Cement," but, as a matter of fact, this cement was only "natural cement," and is absolutely useless for concrete block making and concrete products. It may be said by some who have tried this cement that they have found it very good, but the writer has known cases where one or two consignments have turned out excellent and the next four or five have been just as bad, and all the products made with it have had to be thrown away and a good reputation lost.

It is sometimes necessary to make a rough test of the cement as it is supplied, and perhaps a few practical hints will be welcomed. A common test for cement is to take ½ lb. cement and mix it with 25 per cent. of clean water, and then take a piece of glass (this must be quite clean) and spread the mixture on the glass to a thickness of ¾ in. to 1 in. The glass should be well tapped on the underneath so as to force all the air out of the "pat," as the mixture is now termed. Upon looking at the underneath side of the glass no small holes should be visible. Next place a damp cloth over it and leave for a day (twenty-four hours), then remove the cloth and put in a warm oven until it has a dry and white appearance. Remove the pat from the glass, and the under side, the side next to the glass, should be absolutely smooth and free from cracks. If such is the case the cement can be used with perfect safety. Another test is to fill a test tube with the same mixture as mentioned in the last test and leave it to harden off, making sure, first of all, that all the air is out of the mixture. If it is good cement of first-class quality it should neither contract nor expand, but if it contracts the cement will become loose and will rattle in the tube, and if it expands it will break the tube.

Water.— Before leaving the question of aggregates a word as to the water to be used in the mixing of concrete will not be out of place, as in many cases enough care is not taken, and no thought is given to the kind of water which is best to be used in concrete work. The best water for concrete work is fresh water, and on no account must water be used which has any organic matter or alkalis or acids in it, as these will affect the article being made. It has been said that sea-water will harm concrete, but it will only affect the time taken in setting, and this will take longer than with fresh water, but the final strength of the concrete will not be affected.

Cleansing of Aggregates. — In the case of sand and gravel which are dirty, *i.e.*, contain loam or clay, it is necessary to wash some to take away these impurities. This can be done either by hand or with a mechanical washer, or, if a trough, as shown in *Fig* 1, is used, and water is continually running into it, it will be found that as the sand is shovelled in, the loam will wash away and overflow at the ends. If the sand is stirred about either with a shovel or rake it will make doubly sure that it is perfectly clean. The other way of washing sand needs no explaining here, as it is well known to every builder, *i.e.*, the method of washing sand through a sieve in a tank of water. The only point to be kept in view is that a plentiful supply of clean

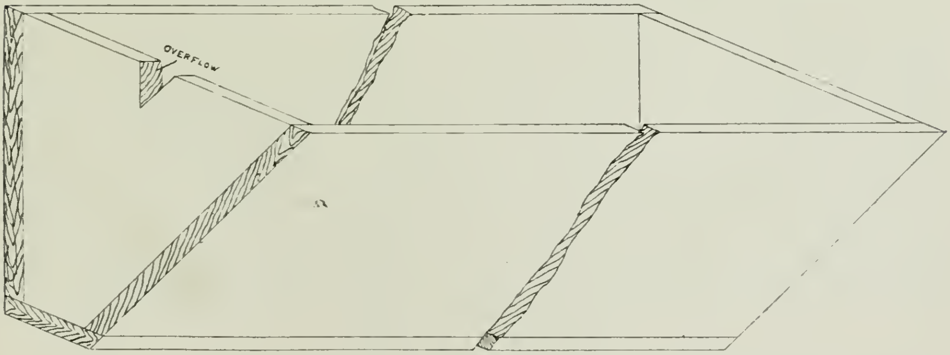


FIG. 1. TROUGH FOR WASHING SAND.

water is needed, for if the water reaches the stage when it will not carry any more loam it will settle on the top of the washed sand that is in the bottom of the tank or tub, and it will be found that the sand contains layers of clay or loam. To avoid this, a good supply of clean water is necessary, and should the water be allowed to settle the sand should be well stirred with a shovel before commencing washing again. To free coke breeze of ammonia and sulphur it will be necessary to "air" it. To "air" it is to spread it out to a thickness of about $1\frac{1}{2}$ in. and well water it two or three times a day for a week. This will tend to free it of these impurities.

Granite, sandstone, and flint stones which have been crushed should all be washed, to free them from the fine dust which is bound to be found in all materials that have been crushed.

Mixing of Concrete. — The mixing of concrete can be done either by hand or with a mechanical mixer. If a large amount of concrete is required it will be found best to invest in a mixer. There are several different makes now on the market, and they can be divided into two groups: (1) the batch mixer and (2) the continuous mixer. The batch mixers are the best. Mechanical mixing is the most economical and the best. When mixing by hand the following practice will be found a very simple one:—Make a box without top or bottom that will hold four, five, or six cubic feet according to the proportions required to be used. Fill it with material (aggregate) and lift box off, spread out on the mixing floor, and next take a box that will hold one cubic foot and fill it with cement. Empty this and spread over the aggregate, and then shovel the whole into a heap. Then begin to turn the heap over from one place to another, turning it backwards and forwards several times until, when drawing the back of the shovel over it, it presents an even colour. You then know that it is thoroughly mixed. Another method is to turn it over two or three times (making sure that it is turned over, and not just shovelled from one spot to another), and then put the whole through a sieve slightly larger in the mesh than for aggregates, *i.e.*, supposing the aggregate is $\frac{1}{4}$ in. downward, the mesh of the sieve should be $\frac{3}{8}$ in. This allows the mixture to go through freely without retaining any on the sieve. This method ensures thorough mixing, providing the heap is turned over two or three times first. Next spread the mixture out over the mixing floor again and water (with a can which has a fine rose) to a consistency which is termed "semi-dry." This consistency is gained by experience better than it can be explained, but the material is wetted just sufficient for it to hold together, and yet not wet enough for it to stick to the mould or lose its shape upon being released from the mould. No set rule can be laid down, as the quantity of water varies according to the aggregates and the mixture used. For instance, one batch of material mixed with sand which has been stored in the dry for some time may take four cans of water to wet it to the required consistency, whilst the next batch that is mixed, where the proportions are exactly the same, but the mixture is composed of sand that has come straight from the pit, only two cans of water might be needed. How is this accounted for? Simply because the material from the pit contained a certain amount of water, while the other, which had been stored in the dry, did not contain any water. The same applies in breeze and sand; two cans of water may be required for sand and double the quantity for breeze, owing to the difference in the porosity of the aggregate. So it will be seen quite plainly why no hard or fast rule can be laid down for the quantity of water needed for a certain size batch containing given proportions. Mixing machines have been shown in our columns from time to time.

MOULDS AND MACHINERY FOR THE MANUFACTURE OF CONCRETE BLOCKS.

There are many different makes of moulds and machinery on the market for the making of concrete blocks in such quantities and at such a price that they may be a commercial success. The machines can be divided into two groups: (1) The mechanincal pressure machine; (2) the hand tamping machine. The pressure machines are all about the same type; that is to say, that the machine compresses the material, the die or press coming down from the top and entering the mould box. Some machines apply more pressure to the block than others, and it is necessary to compress the materials so close together as to fill all the voids. Unless this is done, a waterproof and dense block will not be obtained. It is always best before purchasing a machine for any concrete block work to have the advice of a specialist, so as to get the best machine for the amount of capital to be expended, and he will also be able to advise the best methods of making, curing, etc., of the blocks or any other articles to be manufactured.

Hand tamping machines are more in everyday use than the power or mechanical pressure machines for many reasons: (1) Because they are easy to transport from one place to another; (2) because they are cheaper, and thus within the reach of small builders; (3) because some maintain that stronger blocks are obtained by hand tamping than by the mechanical presses. This question will be dealt with later on under the heading of "How to Make Blocks."

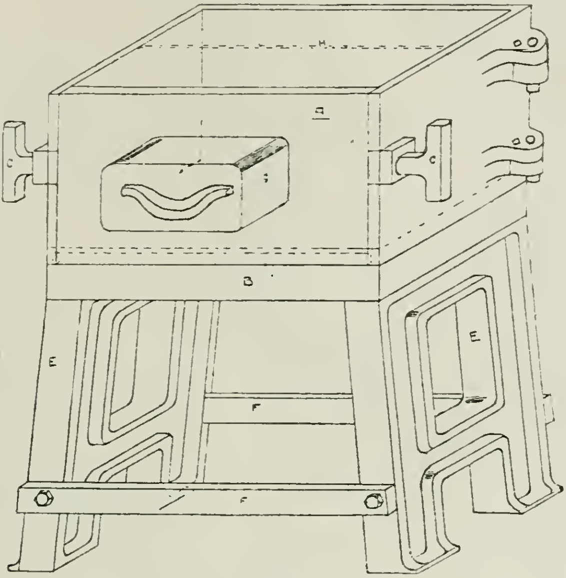


Fig. 2.

A. Mould Box.
B. Bed Plate.
C. Instantaneous Fastener.
D. Hinges.
E. Standards.
F. Stay Bars.
G. Core. This can be hand-worked by a lever.
H. Division for Cavity Blocks.

An illustration of a hollow concrete block machine is given in *Fig.* 2. This represents the general principle of a hand tamping machine. By taking the core (*G*) out and inserting a thin plate in the opening the thickness of the door of the mould box, and also by arranging a division at (*H*) cavity wall, blocks 4½ in. thick can be made.

From time to time illustrations, etc., have been shown in these pages of some of the different makes of machines and moulds upon the market, and if the instructions of this article are followed it will be easy to select a machine to suit the requirements of the different jobs.

MAKING A MOULD FOR CONCRETE BLOCKS.

The size block which has been found from practical experience to be the handiest size for all general work is the one which is 18 in. by 9 in. by 4½ in., or thereabouts. It is always well to have a block of such a size as will give a complete number of blocks to the yard super. If the above size block is adopted it will be found that eight such size blocks will just cover a yard super. This makes it very simple for calculating the number of blocks in a wall which contains so many yards super of block work.

For the purpose of showing how to make a mould for concrete blocks we will adopt this size as the standard size for the blocks. *Fig.* 3 shows the mould constructed without any "liners" on it. It will be seen from this that it has a bottom and a back which are fixtures, while it has two side doors which open out away from the mould. The front also opens and hangs down under the mould. The liners are so arranged that they can be easily taken from the mould and others substituted, so as to make different sized or shaped blocks. By this method the necessity for several moulds is obviated, but at the same time it is quite as convenient.

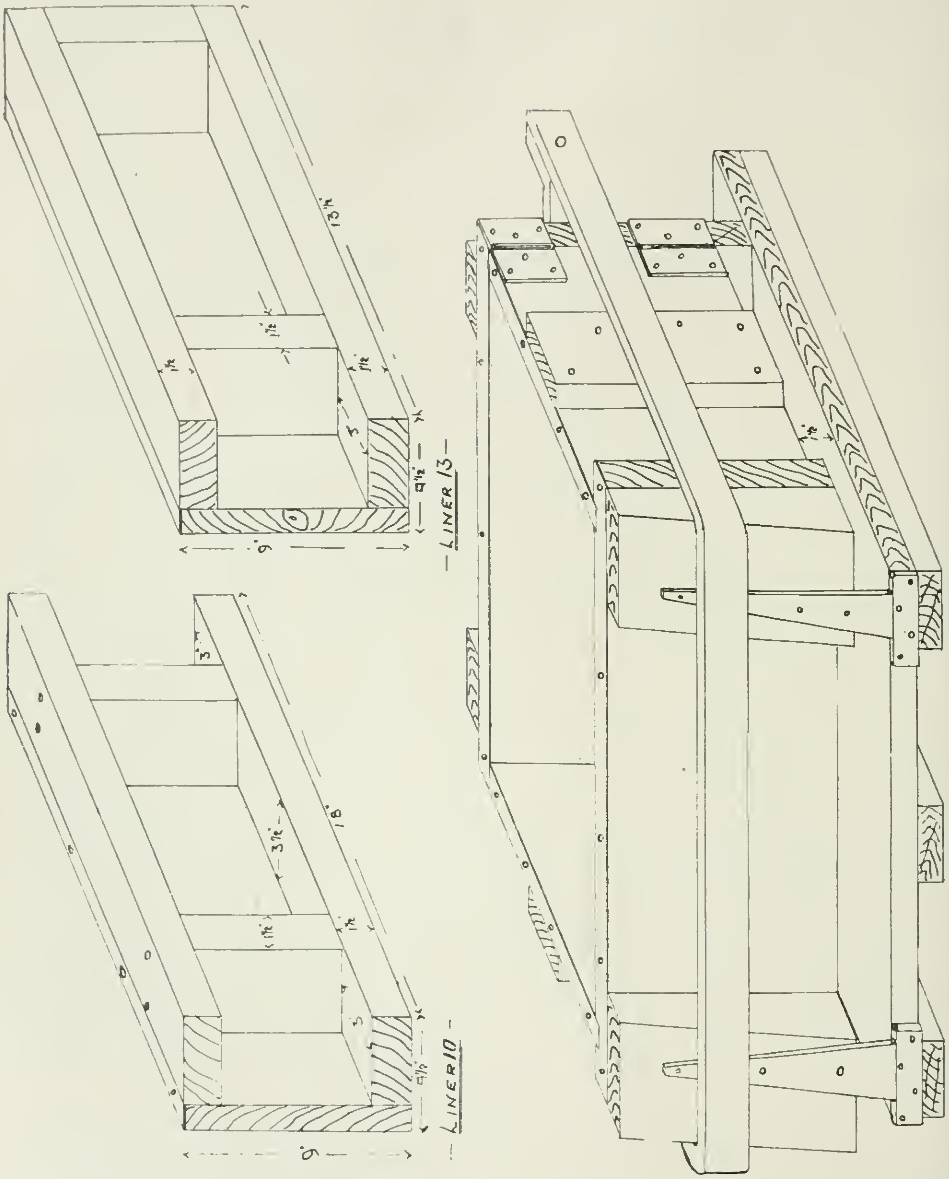


Fig. 3.

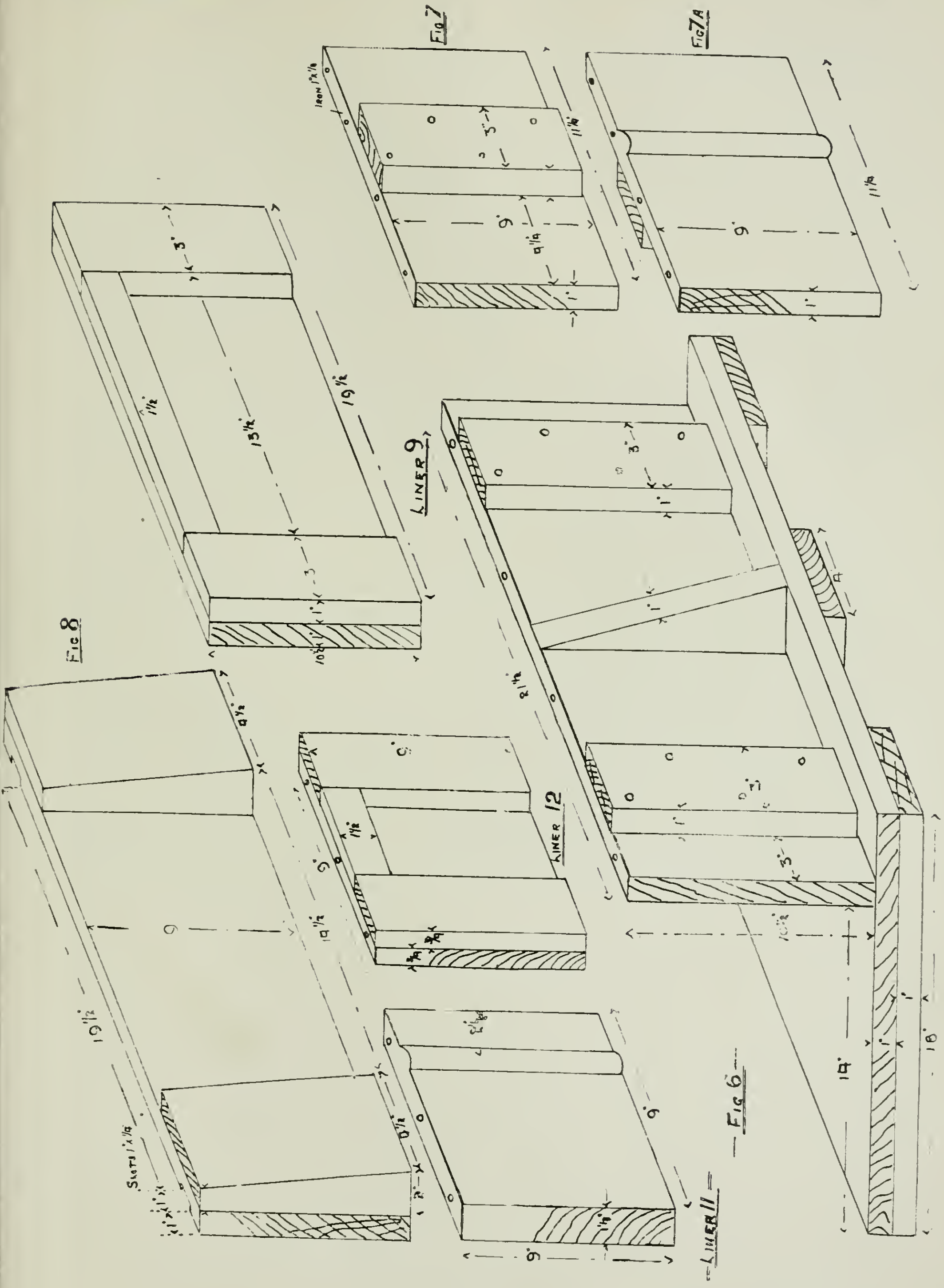
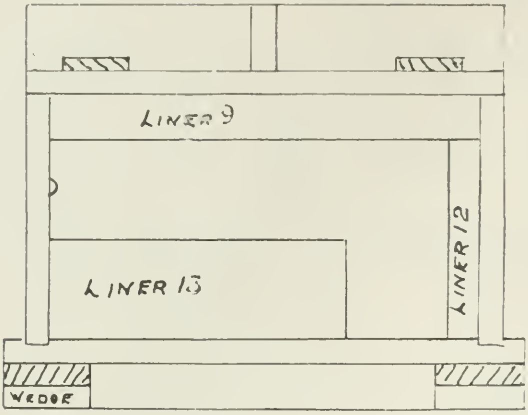


Fig 7
Iron 1"x1/8
3"
9"
9¼
11½
1"
Fig 7A
9"
11½
1"
Fig 8
3"
1½
13½
19½
3
1"
10½
9½
9
19½
Skots 1"x1/4
2"
9½
Liner 9
3"
1"
4
21½
3"
3"
10½
19"
1"
18"
Liner 12
9"
1½
9"
19½
Liner 11
9"
9"
1⅛
Fig 6

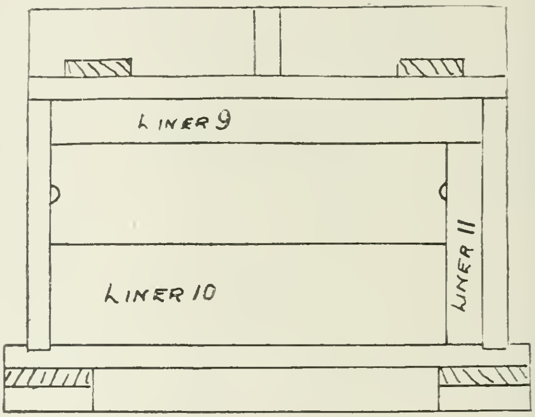
Fig. 5 shows the plan of the mould box fitted with the necessary liners for making ordinary 18-in. by 9-in. by 4½-in. blocks, while *Fig.* 4 gives the plan of the same mould with the liners in their place for making corner blocks.



— FIG 4 —

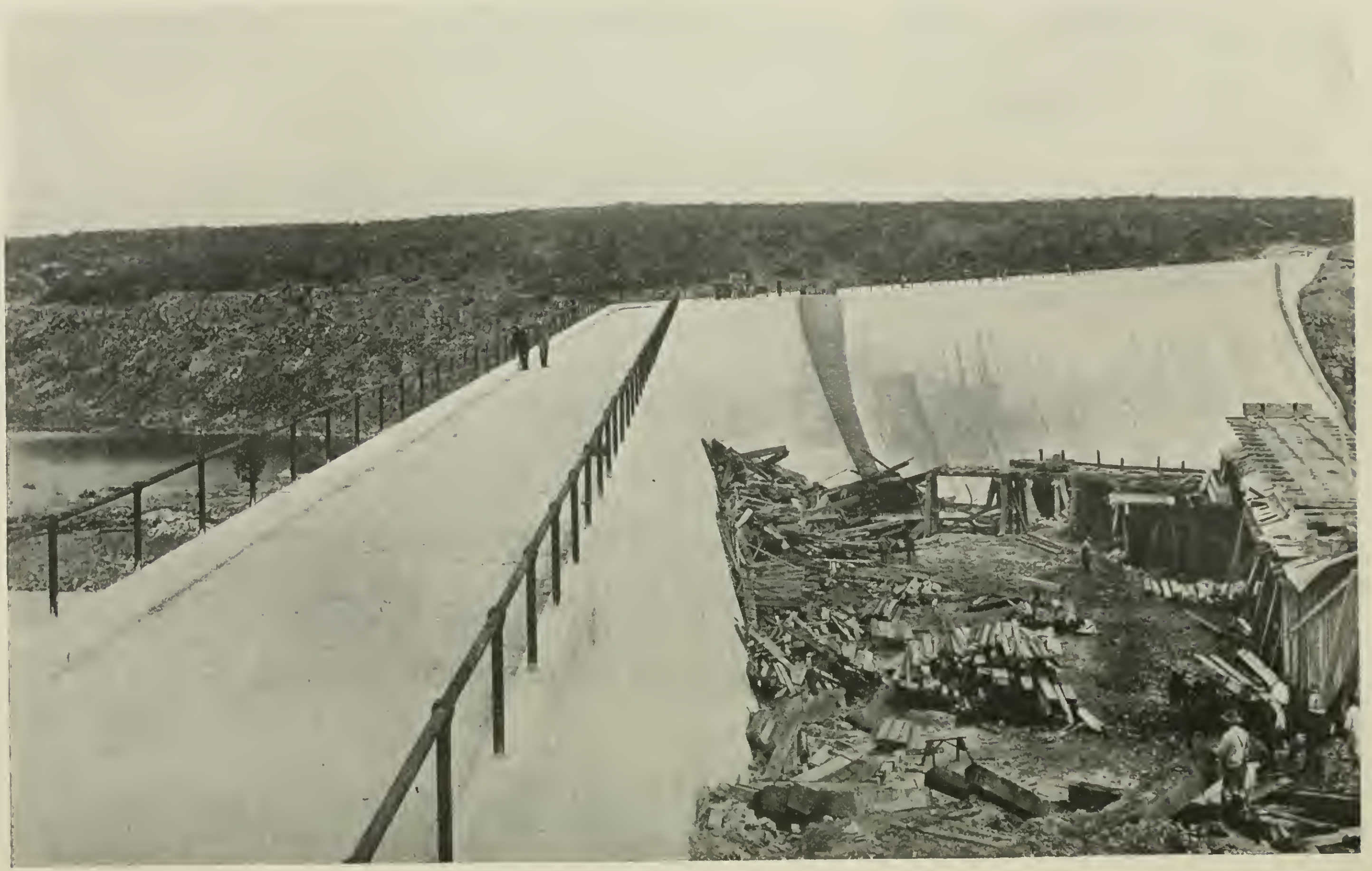
Fig. 6 illustrates the construction of the bottom and back of the mould box in detail, while *Fig.* 7 is the right-hand door. It will be noticed that this and the other two doors are 1½ in. shallower than the back of the mould. When hanging the sides to the back, the top of the mould must be kept level. This will then allow the pallet (see next issue) to lie on the bottom of the mould and the side doors swing over it. There should be just sufficient clearance, so that the doors do not rub the pallet. *Fig.* 7 (*A*) shows the left-hand door with a rib on it, which forms a groove in the block. *Fig.* 8 gives the detail of the front door, and it will be seen that it has two slots in it, and into these slots the side doors, *Figs.* 7 and 7A, fit.

Liner 9 shows the detail of the liner which is fixed to the back of the mould, and is the same for ordinary and for the corner blocks. Liner 10 is also shown in detail, and this fixes to the front door, while Liner 11 is fixed to the right-hand side door. This constitutes the whole mould for the making of blocks 18 in. by 9 in. by 4½ in. All liners should be fixed to the doors, etc., by means of screws from the outside of mould box. This obviates the necessity of damaging the face of the liners by screw holes, which will always show upon the finished article, *i.e.*, the block.



— FIG 5 —

(*To be continued.*)



The Main Concrete Dam in the Medina Valley Irrigation Project, U.S.A.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XI. No. 11. LONDON, NOVEMBER, 1916.

EDITORIAL NOTES.

THE STRENGTH OF CONCRETE.

THE great importance of the methods of mixing concrete, and the effect on the strength of the material, is not fully realised by the majority of engineers, and for this reason special attention is called to the notes which appear in this issue under the heading of " Recent Views."

There is a great tendency to deal with the mixing in what may be termed a " text-book style," when insufficient attention is paid to the nature of the aggregate used and the question of the percentage of water is dismissed in a summary manner as being of secondary consideration. As a matter of fact, the strength of concrete is affected probably more by the method of mixing and the percentage of water than by any other factors in the making.

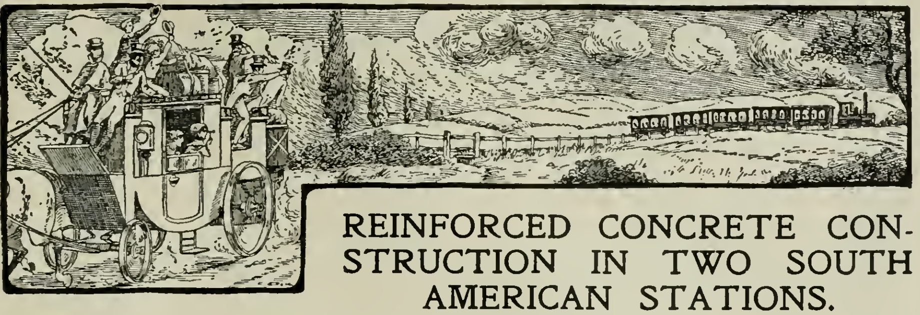
Quite recently a case was brought before our notice which proved, in a very decided manner, how concrete may vary in quality when the same materials and proportions are used, and it may serve as an illustration of the importance of the point. On some large works in this country two separate contractors were engaged on two distinct sections of the scheme, and the concrete for foundation work was specified to be crushed limestone, which was available on the site. The engineer in charge of the work took samples of various materials for testing purposes, and among these were 6-in. cubes of concrete from batches mixed by both contractors. These samples were taken without notice being given, and under identical conditions in each case as the mixing was completed and the material was being transported to the place of deposit. Each contractor's work was under the constant supervision of a clerk of works, one for each section of the scheme, and the materials were similar in all respects as regards aggregate and matrix, and the proportions were identical. Upon the tests being made on the cubes at the expiration of ninety days the results were rather surprising, as the concrete mixed by one contractor was found to have a strength nearly 300 per cent. greater than that of the other. It was not due to any one particular cube giving exceptional results, as the tests in each set were very uniform, and the average in each case was very close to any particular result. The difference between the two contractors' work can only be accounted for in the percentage of water used and the method of mixing; and this example should be sufficient, as an instance of an actual practical case, to convince engineers of the necessity of devoting some attention to the actual making of the concrete in all important work.

We have set up various standards in this country, and the various aggregates for concrete are generally placed in order of merit among engineers without being supported by actual methodical tests which have proved the respective values, and thus the results given in the notes published in this issue are likely to prove a little surprising. We have seen cases when a concrete made of crushed limestone that had been condemned for reinforced concrete work gave much higher results under test than similar concrete made with granite, and thus it is useless to judge materials on theory alone. In the extracts, mentioned above, it will be noticed that the statement is made that no type of gravel or stone aggregate can be said to be generally superior to any other type, and it must be remembered that the statement is made after some 20,000 tests have been made.

Machine mixing is advocated as a result of these tests, and with this view we entirely agree, although there is at times a tendency for machine mixing to be somewhat scamped, due to the temptation to obtain a large output from the machine without due regard to efficient mixing. In hand mixing there is too much of the human element, which is apt to prove unreliable, and although good concrete *can* be made by hand, it is likely to prove the exception rather than the rule, and, furthermore, machine mixing will be found more economical. It is also stated that concrete mixed by different contractors may cause a maximum average variation in the compression strength of 70 per cent. or more. As seen in the example given by us above, it may reach nearly 300 per cent. in practice.

It is quite probable that the relation of the consistency to compression strength as given by the tests will prove to be the greatest surprise to the majority of engineers. We all know that the quantity of water used has an effect on the strength, but there is great divergence of opinion as to the exact consistency which will produce the best results. The common tendency is to add too much water, and generally speaking architects and engineers would prefer too much water rather than too little, and this appears reasonable on the face of it, as in theory water is essential to allow the chemical action of the cement to take place, and if insufficient water is provided the action may be incomplete, whereas an excess of water would not appear likely to prove detrimental. The results of the tests prove, however, that it is better to err on the side of using too little rather than too much water, and the most satisfactory consistency, from the standpoint of strength and durability, is a quaking or mushy mixture. The table which is illustrated in *Fig.* 2 is particularly interesting, as it shows graphically how the strength steadily decreases with the amount of water used. Engineers, as a general rule, consider that a standard of compressive strength can be assumed for concrete made with a particular aggregate and mixed in particular proportions, but this is not the case unless all the other factors which enter into the making are properly controlled, and it is quite possible that only a fractional part of the strength will be obtained unless the actual making is properly dealt with. Too much importance cannot be attached to this aspect of reinforced and other concrete work, as the strength may be affected by as much as 100 per cent. Most building materials are subject to rigid rules and inspection during the manufacture, while concrete, which is one of the most important materials of the present and future, is often made in a careless manner.

Great care is taken in the manufacture of Portland cement, and high standards are called for, and yet a large proportion of the strength of the material, in which this forms a part, is lost either through inexperience or indifference.



REINFORCED CONCRETE CONSTRUCTION IN TWO SOUTH AMERICAN STATIONS.

By ERNEST G. W. SOUSTER, A.R.I.B.A.

The use of reinforced concrete for structures of every description in South America is likely to increase considerably in the near future, and we have pleasure in illustrating here two station buildings in course of construction, showing how reinforced concrete may be advantageously used in station building.—ED.

DURING the past few years the placing, design, and construction of railway stations has been discussed from all points of view by town planning conferences and the technical and lay Press. These articles and reports have almost persuaded the average man that station buildings can only be properly carried out by French or American engineers and architects, and we have, therefore, great pleasure in illustrating these two South American stations which have been designed by an English architect and are being carried out almost entirely by British firms.

It must be mentioned that at present the works are in abeyance; but that is entirely on account of the war, the railways being principally used for the carrying of nitrates, and the termination of hostilities should see the buildings rapidly pushed forward to completion.

Both stations are designed as symmetrical structures, and the character of the elevations, which are designed on a classic motif, is carried into the two booking halls, which form the central features of the design.

Antofagasta, Chili.—The station at Antofagasta, in Chili, was at first designed to be carried out in timber construction, and plans were prepared for this purpose, but before the works were commenced it was decided to use reinforced concrete with a facing of glazed terra cotta for the external walls and those of the booking hall, etc., and reinforced concrete stanchions and partitions in the remainder of the structure. Wood joists, however, are still to be used for the floors, and timber roof principals will carry the roof, which is to be copper covered.

Fig. 1 is part of the foundation plan and shows the setting out and the granite plinth which forms the base to the building. As will be seen from this and the general plan, the building is designed with the large booking hall in the centre of the building and approached from the town by a colonnaded portico.

Four free standing Doric columns with pilaster, responding on either side of this hall, support the main beams which act as basis for the deeply coffered ceiling and also support the floor of the offices over. These columns

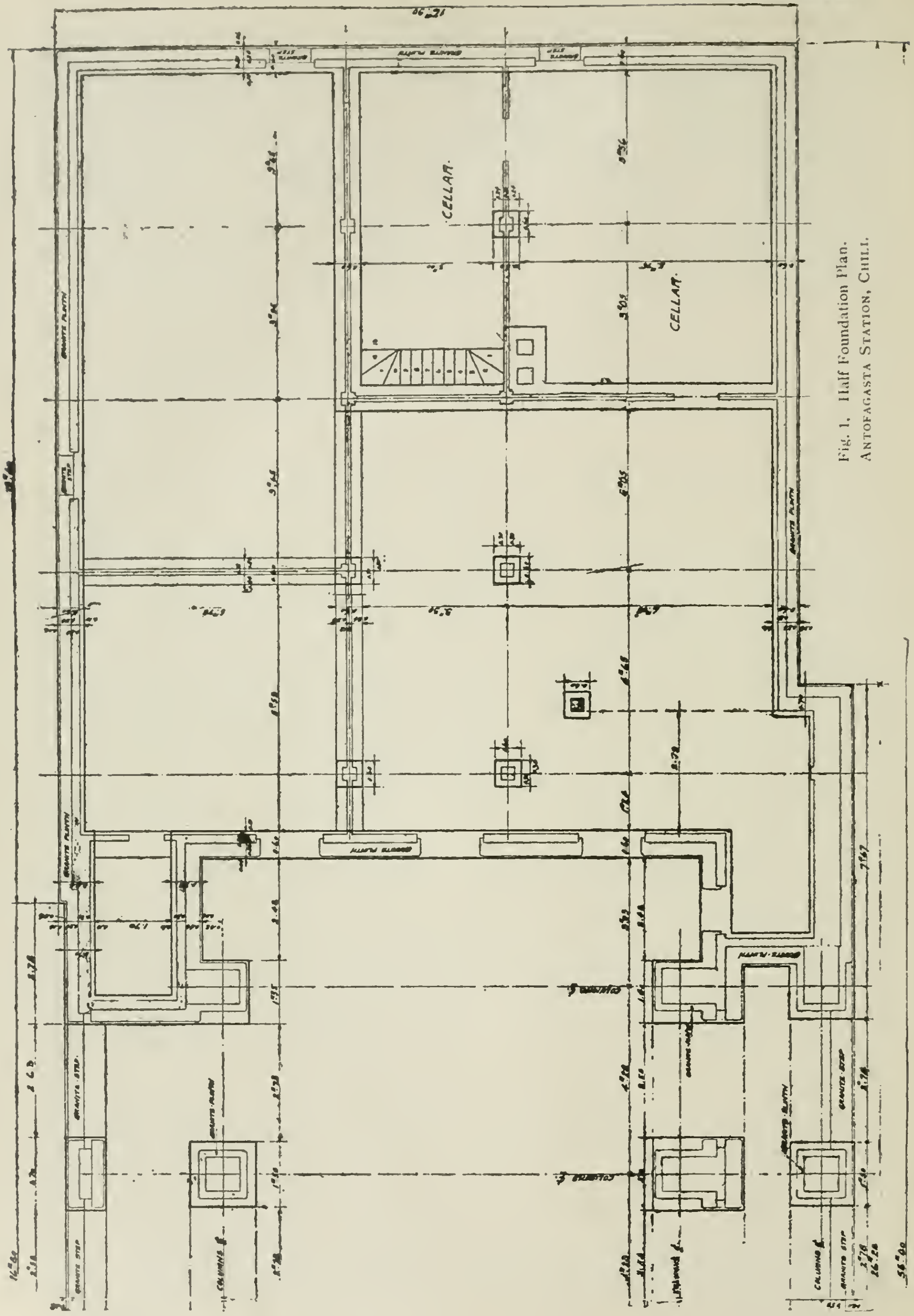
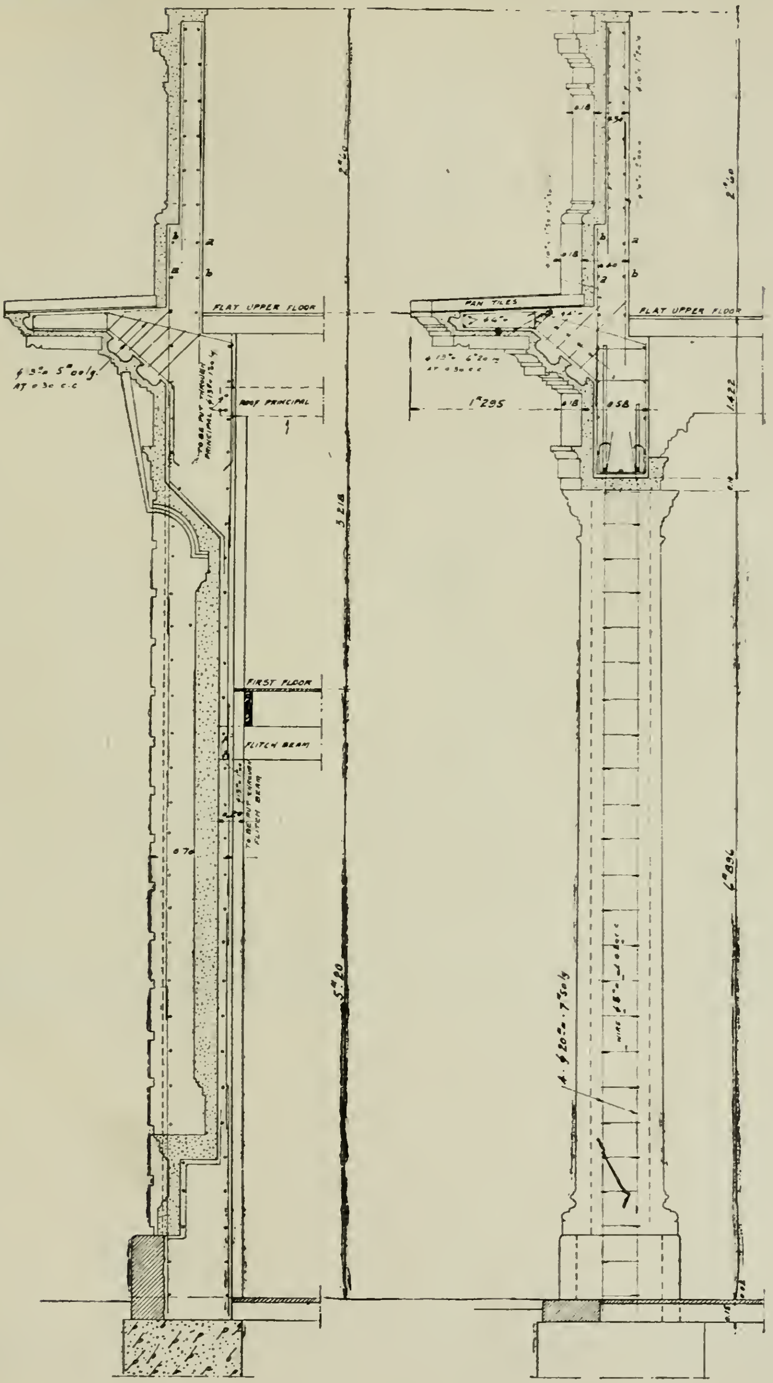


Fig. 1. Half Foundation Plan.
Antofagasta Station, Chili.



·SECTION·D·D·

·SECTION·E·E

Fig. 2.
Antofagasta Station, Chili.

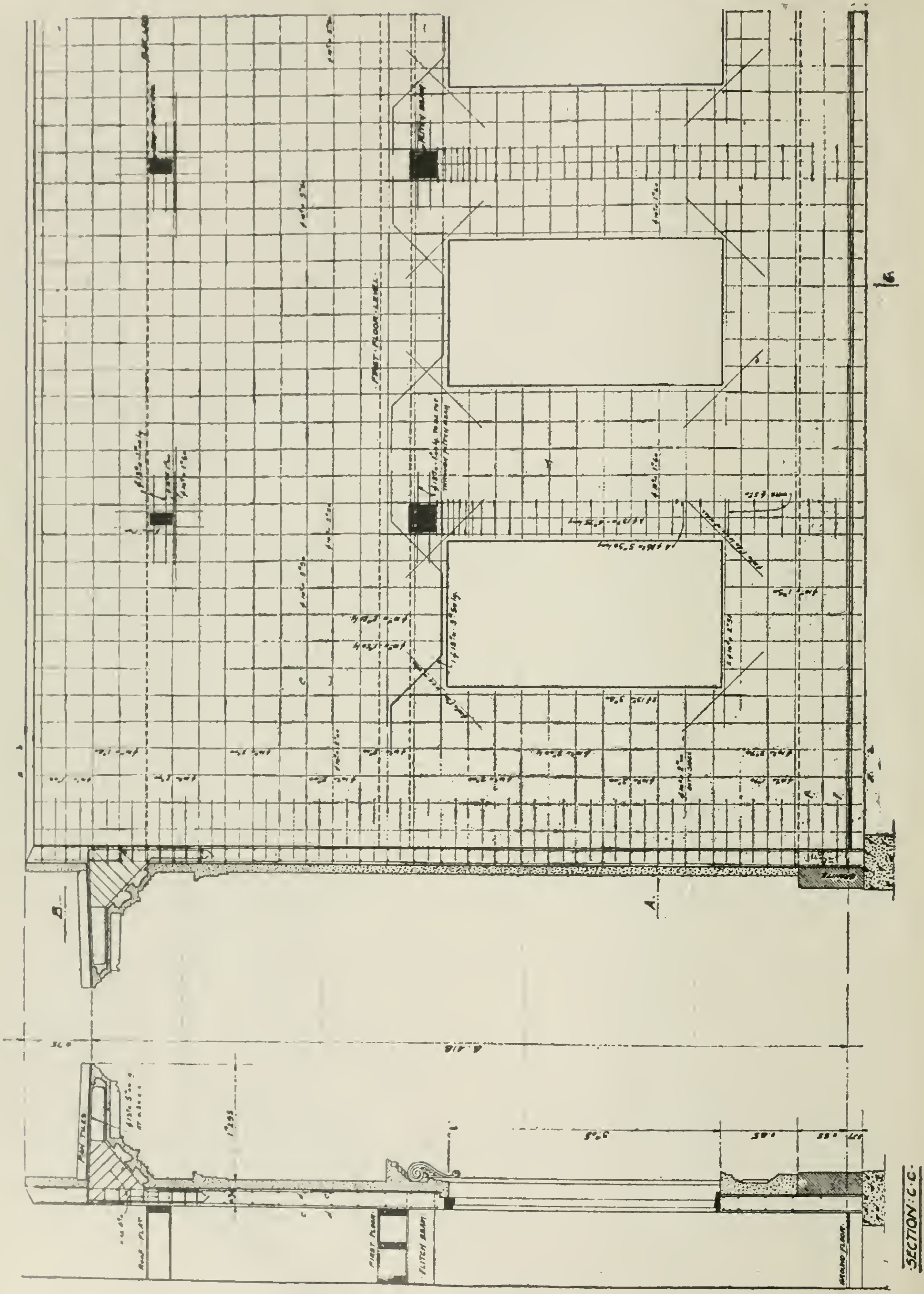


Fig. 3. Part Inside Principal Elevation.
ANTOFAGASTA STATION. CHILI.

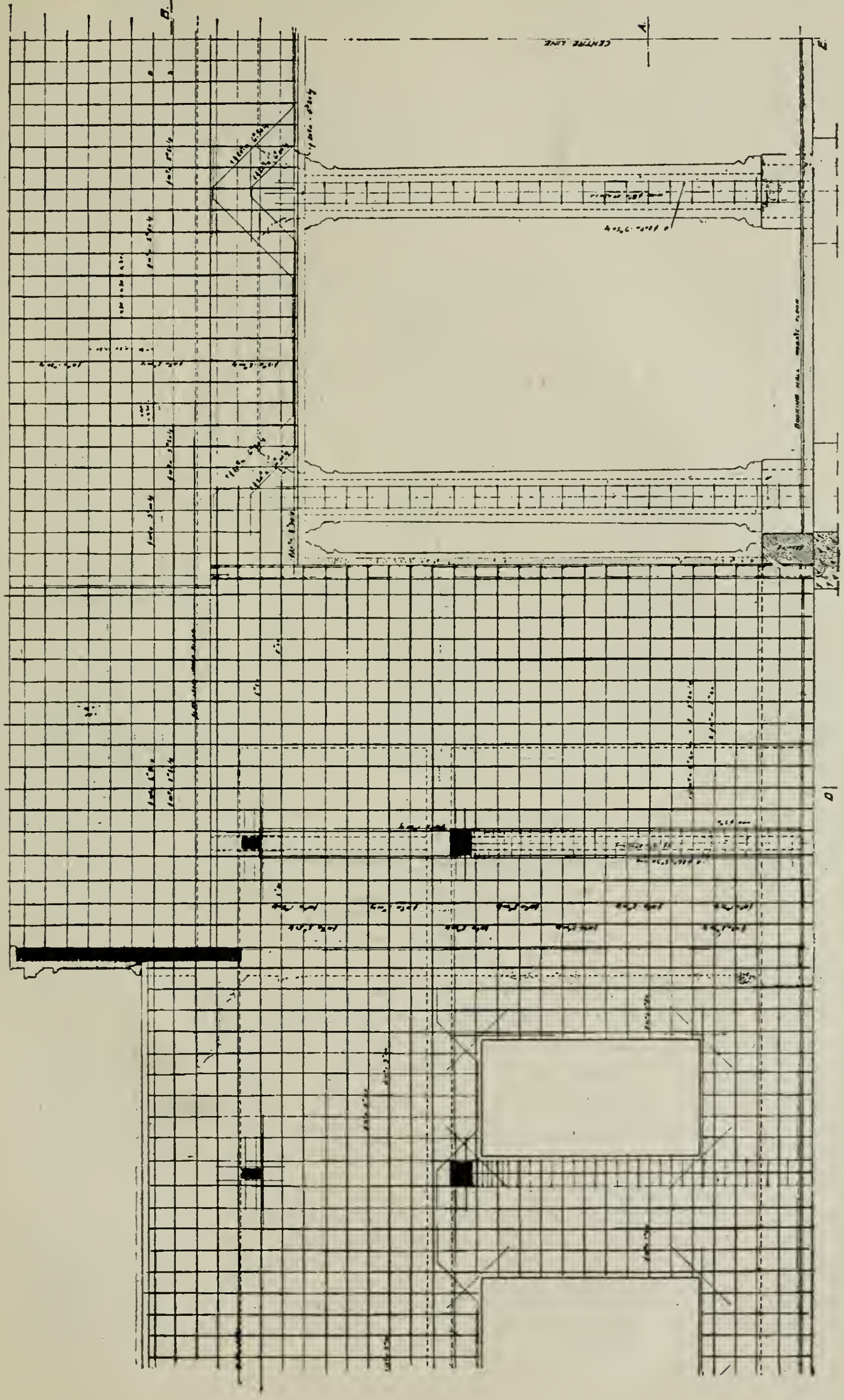


Fig. 4. Part Inside Principal Elevation.
Antofagasta Station, Chili.

are formed with a reinforced concrete core, which acts as a stanchion and supports the whole of the superimposed load, and around them is built a glazed terra-cotta facing.

The general method of construction adopted is shown in *Figs.* 3 and 4, which are sections through the building. On one side of the booking hall are grouped the waiting rooms and refreshment room with kitchen and store adjoining, and on the other side the luggage department and the rooms for the staff. The method of constructing the walls between these departments is shown in *Fig.* 11. A series of reinforced concrete stanchions, arranged at equal distances in order to standardise the construction, carry the whole of the superimposed weights, and between these light reinforced concrete partitions divide the building into the rooms required. It will be seen from this drawing that simplicity of erection has been the keynote of the design, and that the possibility of defective workmanship arising from elaborate bendings and junctions has been entirely eliminated.

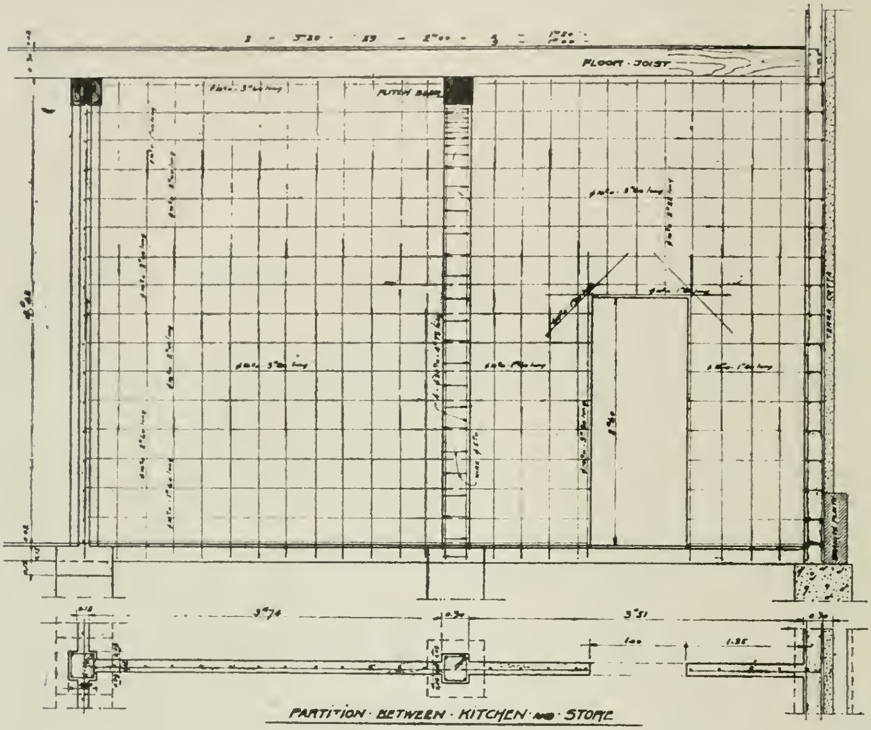
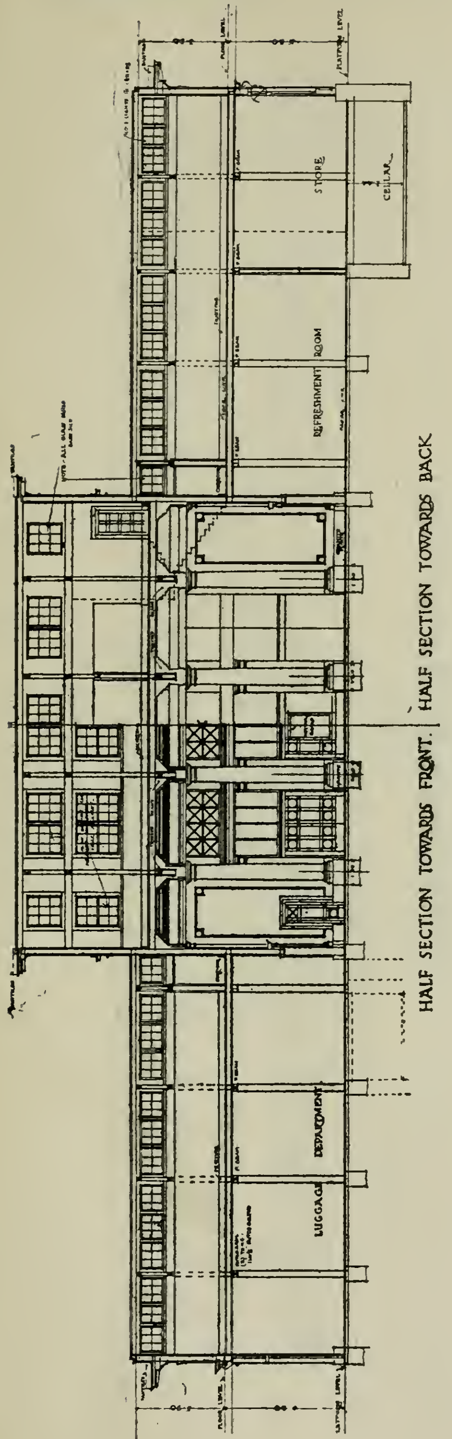
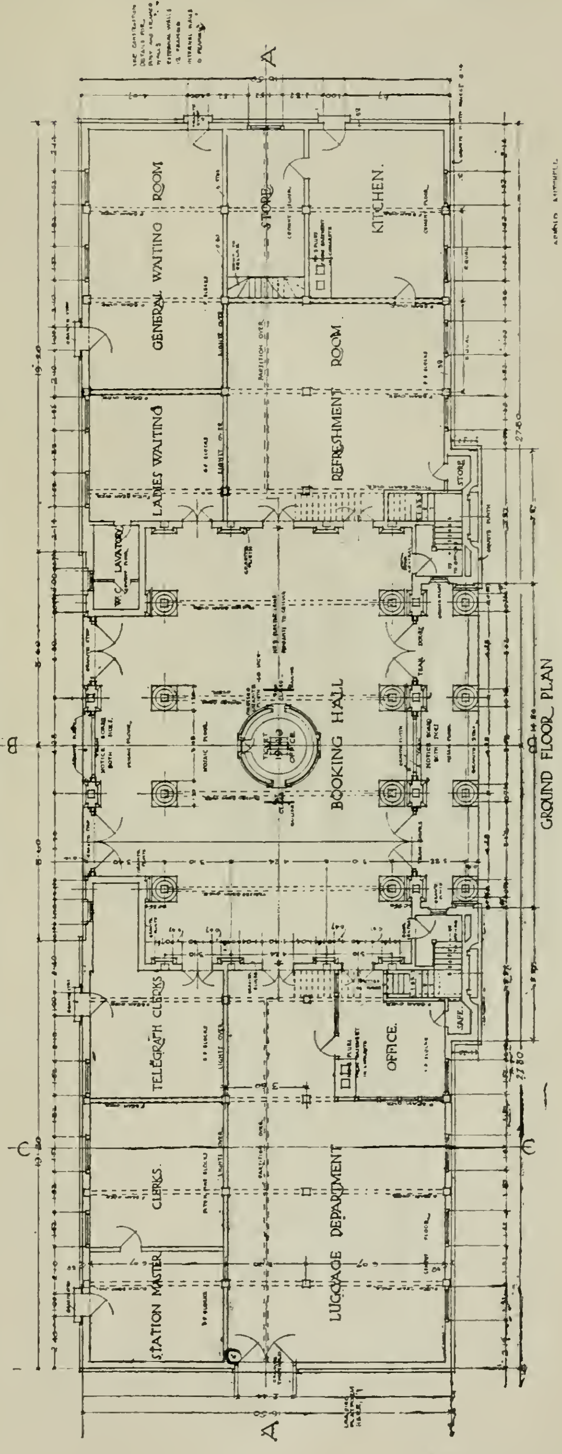


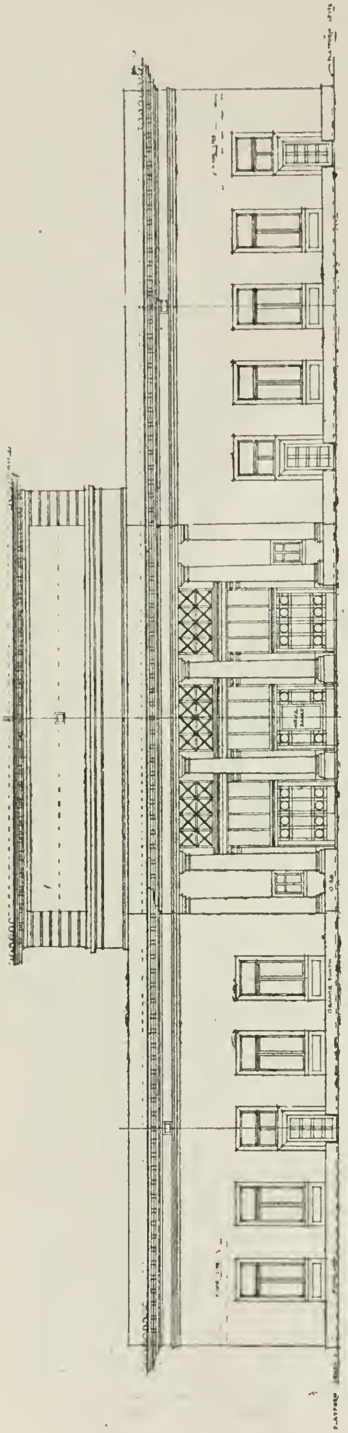
FIG. 5. ANTOFAGASTA STATION, CHILI.

The building being in a hot, sunny climate, a heavy overhanging cornice became a necessity from an architectural point of view, and the constructional problem involved to make it rigid and at the same time to carry the facing has been cleverly solved in a simple manner. *Fig.* 2 shows this detail, which is self-explanatory, and is an interesting example of the use of reinforced con-

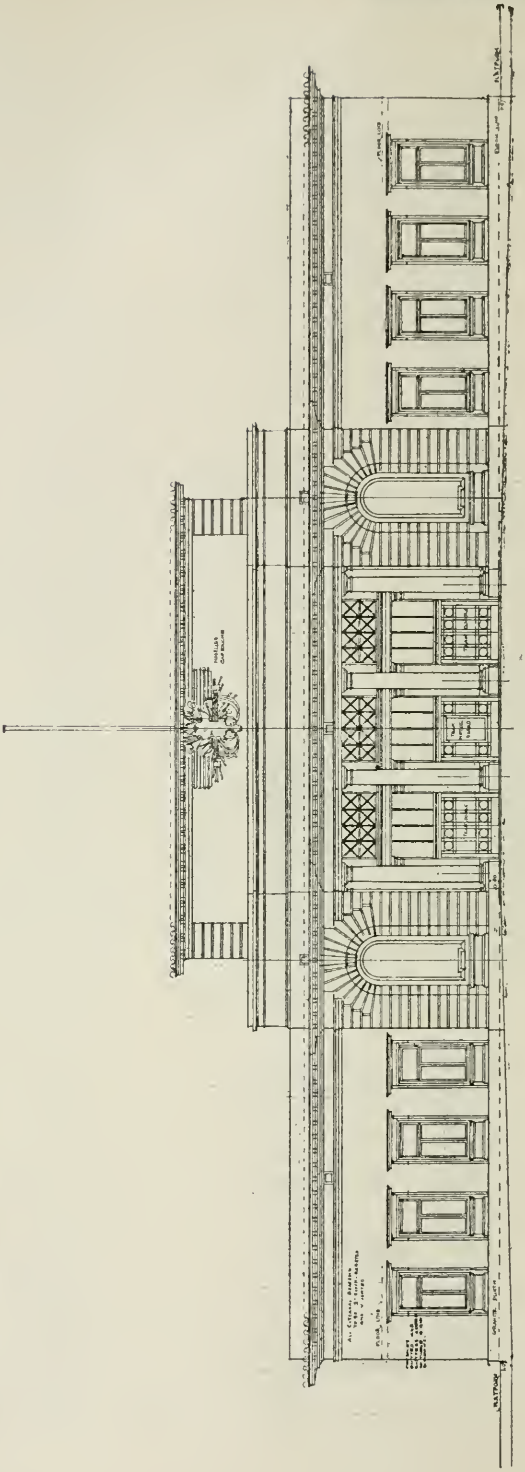




Figs. 6 and 7. Antofagasta Station Chili.

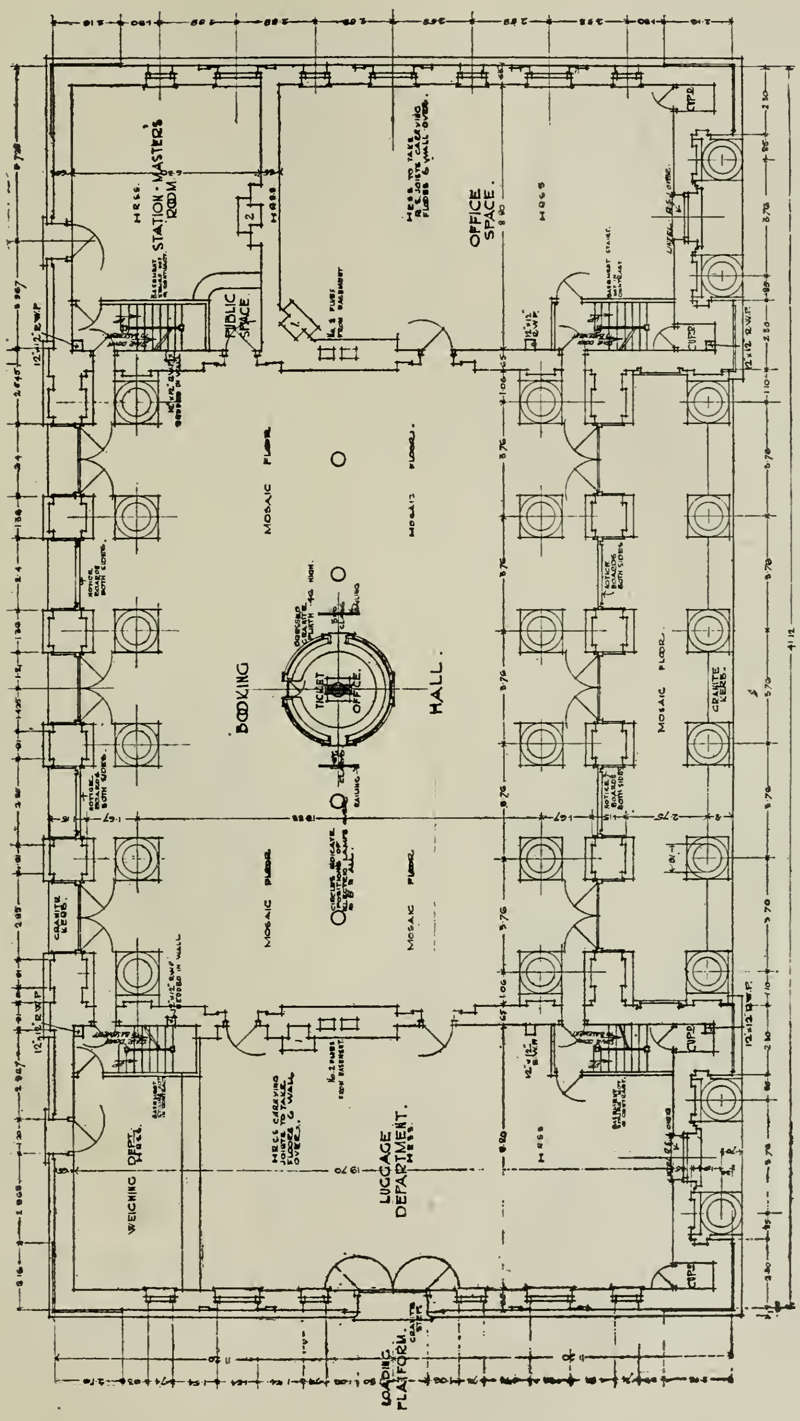


Elevation to Platform.



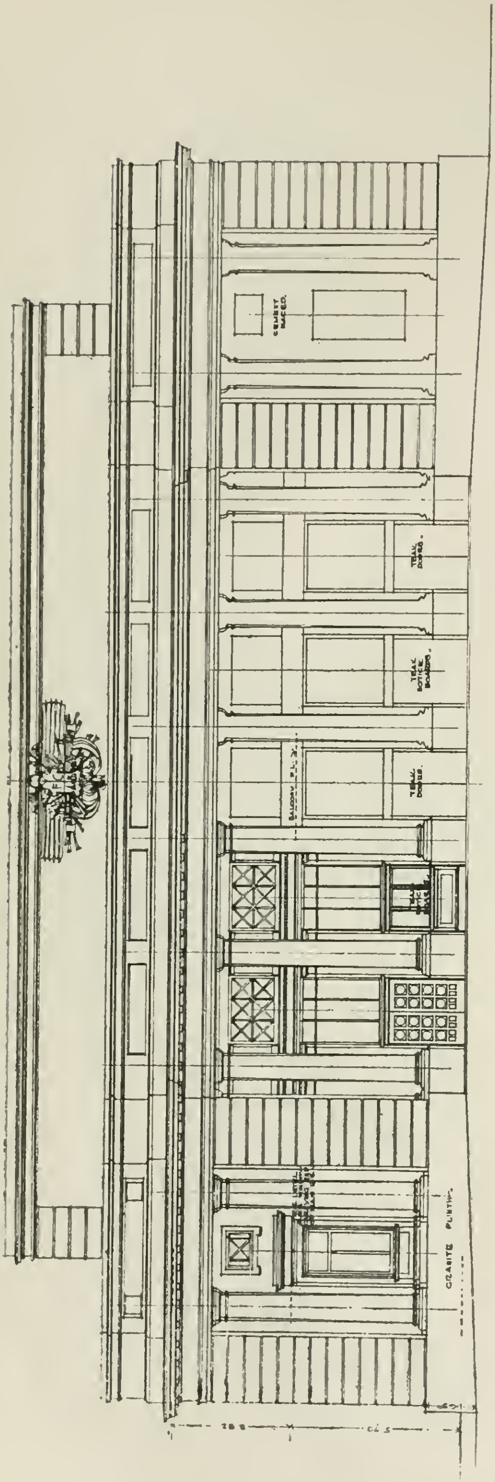
Principal Elevation.

FIGS. 8 AND 9. ANTOFAGASTA STATION, CHILI.



Ground Floor Plan.

FIG. 10. STATION, LA PAZ, BOLIVIA.



Front Elevation to Town.

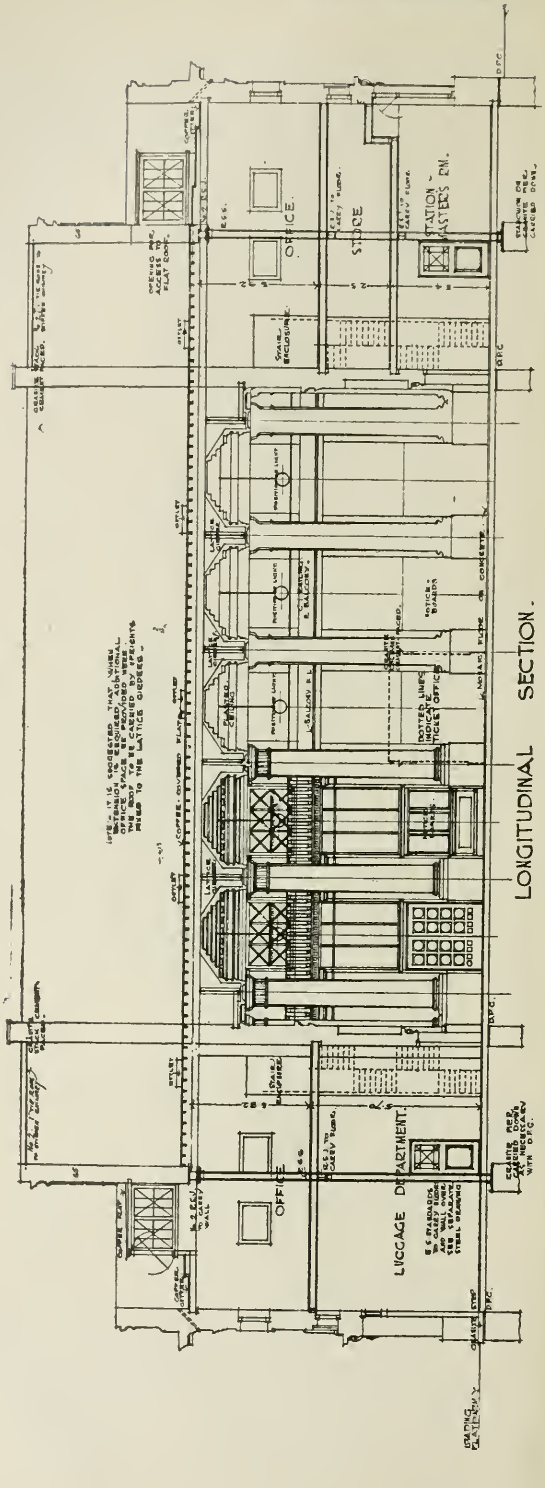

LONGITUDINAL SECTION.
OFFICE.
STORE.
STATION-MASTER'S RM.
STAIR ENCLOSURE.
OPENING FOR ACCESS TO FLAT ROOF.
LATTICE GIRDER.
PLASTER CEILING.
BALCONY F.L.
COPPER COVERED FLAT.
OUTLET
DOTTED LINES INDICATE TICKET OFFICE.
BOTTICE BOARDS.
MOSAIC FLOOR ON CONCRETE.
STAIR ENCLOSURE.
OFFICE
LUGGAGE DEPARTMENT.
GRANITE PIER CARRIED DOWN AS NECESSARY WITH D.P.C.
D.P.C.
GRANITE STEP
GRADING PLATFORM
NOTE:- IT IS SUGGESTED THAT WHEN EXTENSION IS REQUIRED ADDITIONAL OFFICE SPACE BE PROVIDED WHERE THE ROOF TO BE CARRIED BY UPRIGHTS FIXED TO THE LATTICE GIRDERS.

Fig. 11. Station, La Paz, Bolivia.

crete; for, to form such a large cornice in any other material would have involved either much thicker walls, or an expensive and elaborate system of ties and beams to prevent overturning.

La Paz, Bolivia.—The station at La Paz, Bolivia, is of simple construction, the walls being rubble faced with cement stucco, and the floors and roof of timber construction. Steel stanchions are, however, used for all supports within the building, and a feature of the construction is the series of deep lattice girders spanning the booking hall. These at present carry a copper-covered roof, but are designed to support a heavy floor and also the supports for a future roof over it.

As at Antofagasta, these girders are concealed in the heavy coffer beams of the ceiling.

The drawings, which are here reproduced, are well worthy of study, and give all the information required for the work to be done.

The architect for both stations is Mr. Arnold Mitchell, F.R.I.B.A., of 17, Hanover Square, W., the reinforced concrete work for Antofagasta was designed and supplied by the Trussed Concrete Steel Co., Ltd., of Caxton House, Westminster, and the glazed facing is being supplied by Messrs. Doultons, in their Carrara facing material.

RESEARCHES ON REINFORCED CONCRETE BEAMS.

With New Formulæ for Resistance to Shear.

By OSCAR FABER, D.Sc., A.M.Inst.C.E., etc.

Continued from October issue, p. 539.—ED.

SHEAR TESTS ON T *BEAMS (1914 SERIES)* (*continued*).

(c) Results of experiments.

The records of cracks and the loads at which they occurred are given in *Figs.* 44-47.

Photographs of the beams are given in *Figs.* 48-63.

It will be interesting first to take the ultimate loads from *Figs.* 44-47 and compare these with those calculated by R.I.B.A. methods and find the factor of safety by dividing the first by the second. This is done in the following table :—

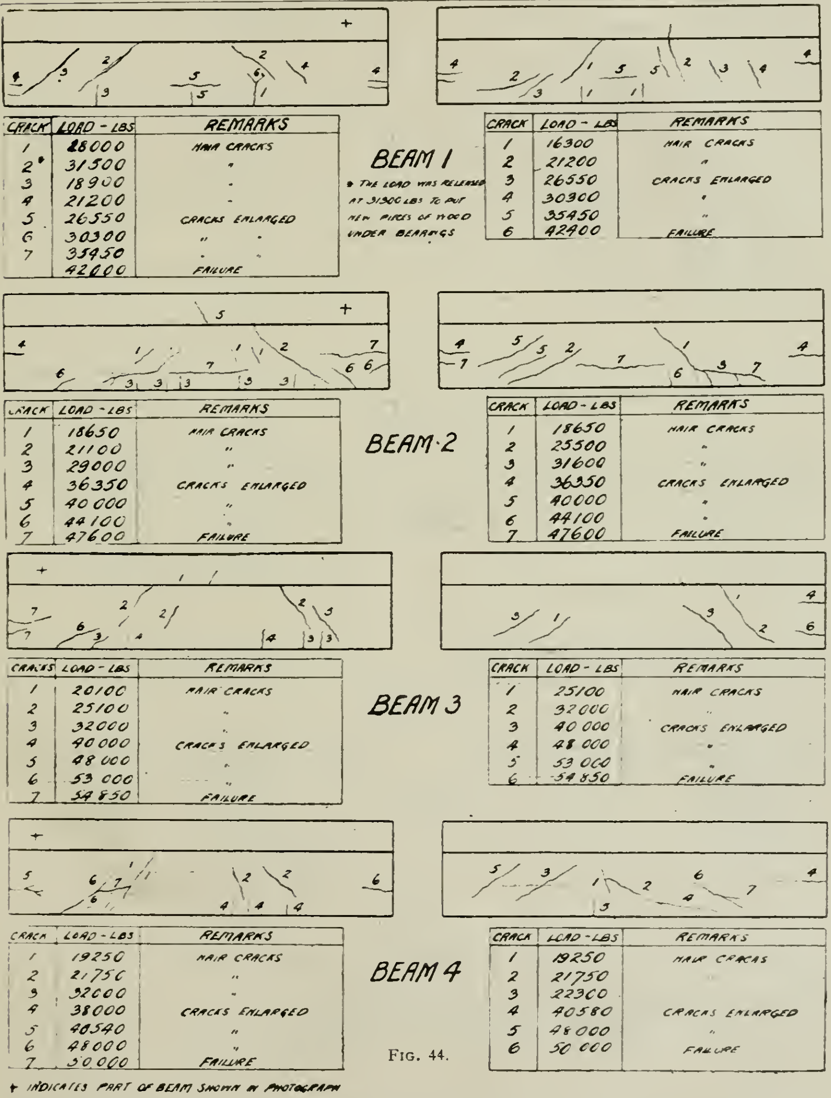
Beam Number.	Safe Load, R.I.B.A.	Ultimate Load.	Factor of Safety.
	lb.	lb.	
1	5,400	42,400	7·85
2	,,	47,600	8·80
3	7,160	54,850	7·64
4	,,	50,000	7·0
5	8,920	50,000	5·6
6	,,	48,500	5·42
7	12,440	56,800	4·54
8	,,	52,600	4·21
9	9,660	41,150	4·30
10	,,	56,800	5·88
11	13,920	57,800	4·15
12	,,	66,500	4·78
13	18,960	54,800	2·89
14	,,	55,680	2·93
15	15,720	63,070	4·02
16	,,	64,500	4·12

Comparing now L.C.C. safe loads with observed ultimate loads in the same way, we have—

Beam Number.	Safe Load, L.C.C.	Ultimate Load.	Factor of Safety.
	lb.	lb.	
1	5,400	42,400	7·85
2	,,	47,600	8·80
3	5,400	54,850	10·2
4	,,	50,000	9·27
5	5,400	50,000	9·27
6	,,	48,500	8·99
7	7,040	56,800	8·1
8	,,	52,600	7·5
9	5,400	41,150	7·63
10	,,	56,800	10·5
11	8,520	57,800	6·8
12	,,	66,500	7·8
13	13,560	54,800	4·05
14	,,	55,680	4·1
16	,,	64,500	6·3

We will now make the same comparison with the safe load as calculated by the writer's method and the ultimate load—

Beam Number.	Safe Shear.	Safe Load.	Ultimate Load.	Factor of Safety.
	lb.	lb.	lb.	
1	6,670	13,340	42,400	3·2
2	"	"	47,600	3·6
3	7,160	14,320	54,850	3·8
4	"	"	50,000	3·5
5	7,600	15,320	50,000	3·3
6	"	"	48,500	3·2
7	8,500	17,000	56,800	3·3
8	"	"	52,600	3·1
9	7,735	15,470	(41,150)	(2·7)*
10	"	17,600	56,800	3·2
11	8,800	17,600	57,800	3·3
12	10,930	21,860	66,500	3·1
13	9,670	19,340	54,800	2·8
14	"	"	55,680	2·9
15	9,210	18,420	63,070	3·4
16	"	"	64,500	3·5
				3·3 mean



BEAM 1

CRACK	LOAD - LBS	REMARKS
1	28000	HAIR CRACKS
2*	31500	"
3	18900	"
4	21200	"
5	26550	CRACKS ENLARGED
6	30300	"
7	35450	"
	42000	FAILURE

* THE LOAD WAS RELEASED AT 31500 LBS TO PUT NEW PIECES OF WOOD UNDER BEARINGS

CRACK	LOAD - LBS	REMARKS
1	16300	HAIR CRACKS
2	21200	"
3	26550	CRACKS ENLARGED
4	30300	"
5	35450	"
6	42400	FAILURE

BEAM·2

CRACK	LOAD - LBS	REMARKS
1	18650	HAIR CRACKS
2	21100	"
3	29000	"
4	36350	CRACKS ENLARGED
5	40 000	"
6	44 100	"
7	47600	FAILURE

CRACK	LOAD - LBS	REMARKS
1	18650	HAIR CRACKS
2	25500	"
3	31600	"
4	36350	CRACKS ENLARGED
5	40000	"
6	44100	"
7	47600	FAILURE

BEAM 3

CRACKS	LOAD - LBS	REMARKS
1	20100	HAIR CRACKS
2	25100	"
3	32000	"
4	40 000	CRACKS ENLARGED
5	48 000	"
6	53 000	"
7	54 850	FAILURE

CRACK	LOAD - LBS	REMARKS
1	25100	HAIR CRACKS
2	32000	"
3	40 000	CRACKS ENLARGED
4	48 000	"
5	53 000	"
6	54 850	FAILURE

BEAM 4

CRACK	LOAD - LBS	REMARKS
1	19250	HAIR CRACKS
2	21750	"
3	32000	"
4	38000	CRACKS ENLARGED
5	40540	"
6	48000	"
7	50 000	FAILURE

CRACK	LOAD - LBS	REMARKS
1	19250	HAIR CRACKS
2	21750	
3	22300	
4	40580	CRACKS ENLARGED
5	48000	"
6	50 000	FAILURE

FIG. 44.

+ INDICATES PART OF BEAM SHOWN IN PHOTOGRAPH

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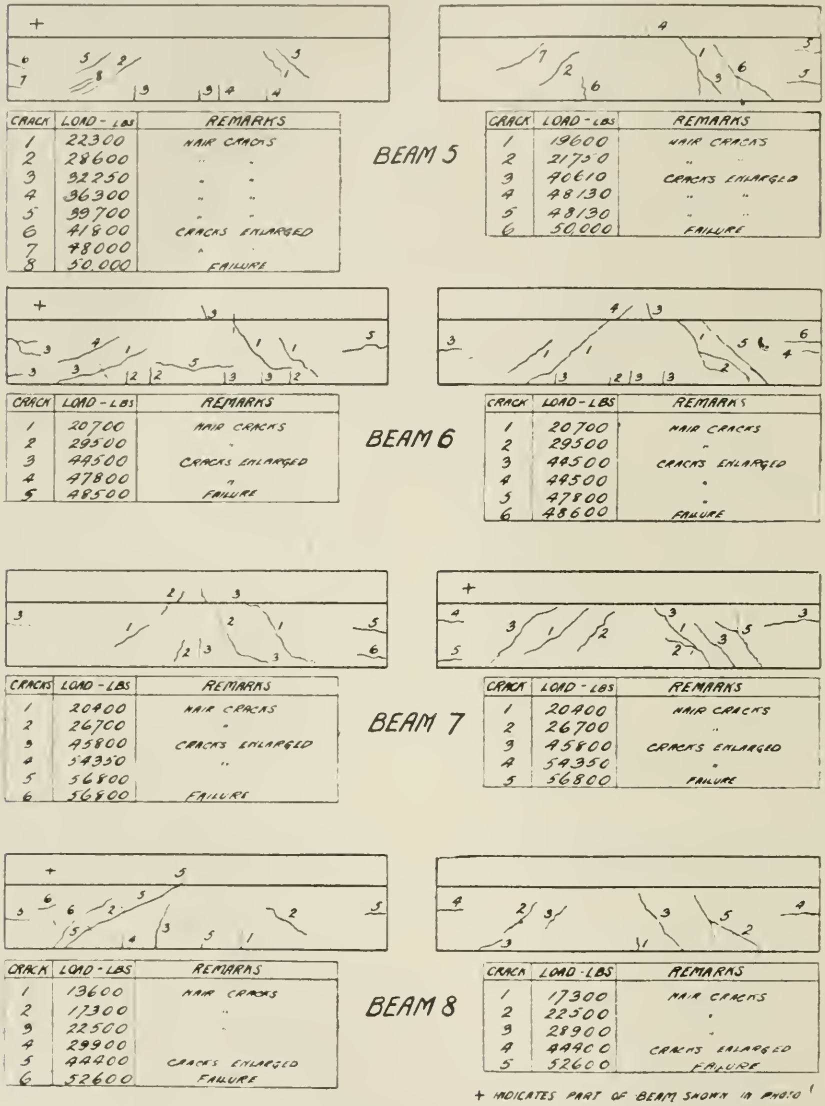
* The experimental notes state that the ultimate load for beam 9 was not obtained. but was known to be greater than 41,150. Hence no value attaches to the figures in brackets.

Note that the factor of safety of 3·3 agrees exactly with what we should expect from a consideration of the tested ultimate strength of the steel (23·8 tons) and the safe load of 16,000 lb./in.² used in the formulæ, since $\frac{23{\cdot}8 \times 2240}{16000} = 3{\cdot}3$. This is strong evidence in favour of the correctness of the writer's formulæ.



BEAM 5

CRACK	LOAD - LBS	REMARKS
1	22300	HAIR CRACKS
2	28600	.. ..
3	32250	.. ..
4	36300	.. ..
5	39700	.. ..
6	41800	CRACKS ENLARGED
7	48000	.. ..
8	50,000	FAILURE

CRACK	LOAD - LBS	REMARKS
1	19600	HAIR CRACKS
2	21750	.. ..
3	40610	CRACKS ENLARGED
4	48130	.. ..
5	48130	.. ..
6	50,000	FAILURE

BEAM 6

CRACK	LOAD - LBS	REMARKS
1	20700	HAIR CRACKS
2	29500	..
3	44500	CRACKS ENLARGED
4	47800	..
5	48500	FAILURE

CRACK	LOAD - LBS	REMARKS
1	20700	HAIR CRACKS
2	29500	..
3	44500	CRACKS ENLARGED
4	44500	..
5	47800	..
6	48600	FAILURE

BEAM 7

CRACKS	LOAD - LBS	REMARKS
1	20400	HAIR CRACKS
2	26700	..
3	45800	CRACKS ENLARGED
4	54350	..
5	56800	
6	56800	FAILURE

CRACK	LOAD - LBS	REMARKS
1	20400	HAIR CRACKS
2	26700	..
3	45800	CRACKS ENLARGED
4	54350	..
5	56800	FAILURE

BEAM 8

CRACK	LOAD - LBS	REMARKS
1	13600	HAIR CRACKS
2	17300	..
3	22500	..
4	29900	
5	44400	CRACKS ENLARGED
6	52600	FAILURE

CRACK	LOAD - LBS	REMARKS
1	17300	HAIR CRACKS
2	22500	..
3	28900	..
4	44900	CRACKS ENLARGED
5	52600	FAILURE

+ INDICATES PART OF BEAM SHOWN IN PHOTO

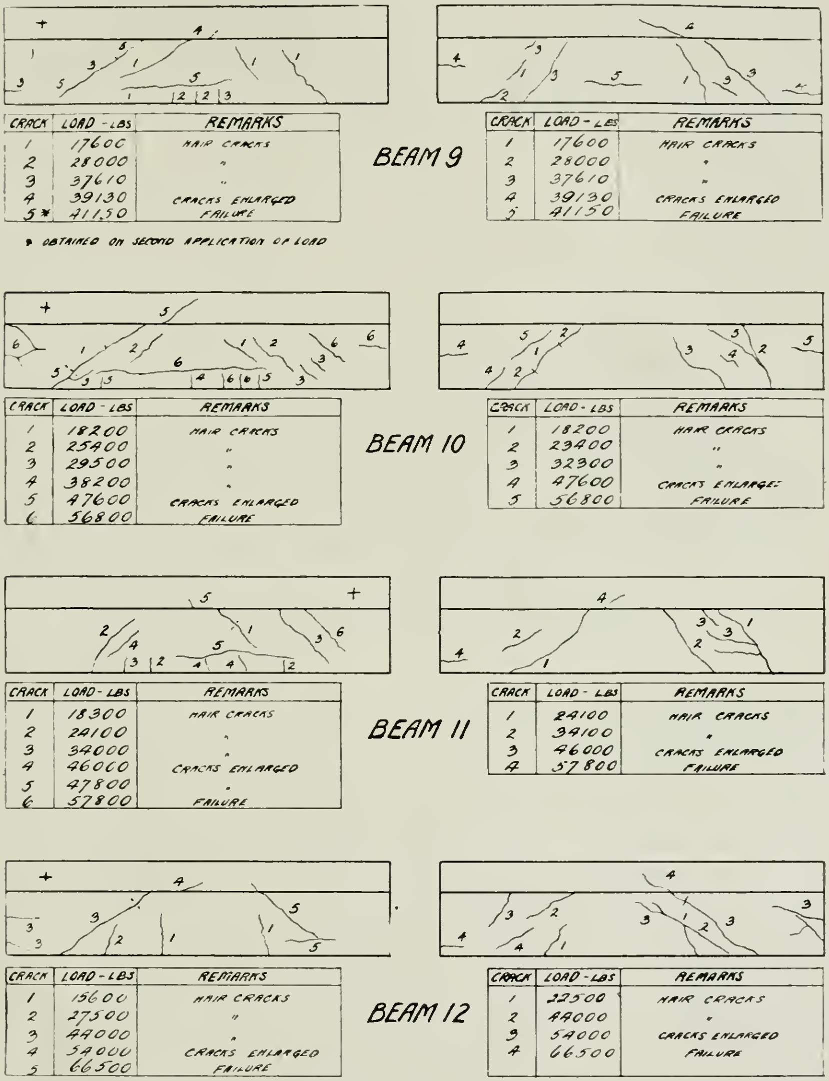
FIG 45

It will be seen that the R.I.B.A. method gives factors varying from 8·8 to 2·9.

The L.C.C. methods give factors varying from 10·5 to 4.

The writer's method gives factors varying from 3·8 to 2·8.

It would be seen that the series of experiments bears out in a remarkable manner the inclined compression theory as outlined in Part III. of this thesis, having regard to the greater variation in the size and arrangement of shear members in the series, and to the necessary variation of hand-made concrete made at different dates by practical workmen.



BEAM 9

CRACK	LOAD - LBS	REMARKS
1	17600	HAIR CRACKS
2	28000	"
3	37610	"
4	39130	CRACKS ENLARGED
5*	41150	FAILURE

* OBTAINED ON SECOND APPLICATION OF LOAD

CRACK	LOAD - LBS	REMARKS
1	17600	HAIR CRACKS
2	28000	"
3	37610	"
4	39130	CRACKS ENLARGED
5	41150	FAILURE

BEAM 10

CRACK	LOAD - LBS	REMARKS
1	18200	HAIR CRACKS
2	25400	"
3	29500	"
4	38200	"
5	47600	CRACKS ENLARGED
6	56800	FAILURE

CRACK	LOAD - LBS	REMARKS
1	18200	HAIR CRACKS
2	23400	"
3	32300	"
4	47600	CRACKS ENLARGED
5	56800	FAILURE

BEAM 11

CRACK	LOAD - LBS	REMARKS
1	18300	HAIR CRACKS
2	24100	"
3	34000	"
4	46000	CRACKS ENLARGED
5	47800	"
6	57800	FAILURE

CRACK	LOAD - LBS	REMARKS
1	24100	HAIR CRACKS
2	34100	"
3	46000	CRACKS ENLARGED
4	57800	FAILURE

BEAM 12

CRACK	LOAD - LBS	REMARKS
1	15600	HAIR CRACKS
2	27500	"
3	44000	"
4	54000	CRACKS ENLARGED
5	66500	FAILURE

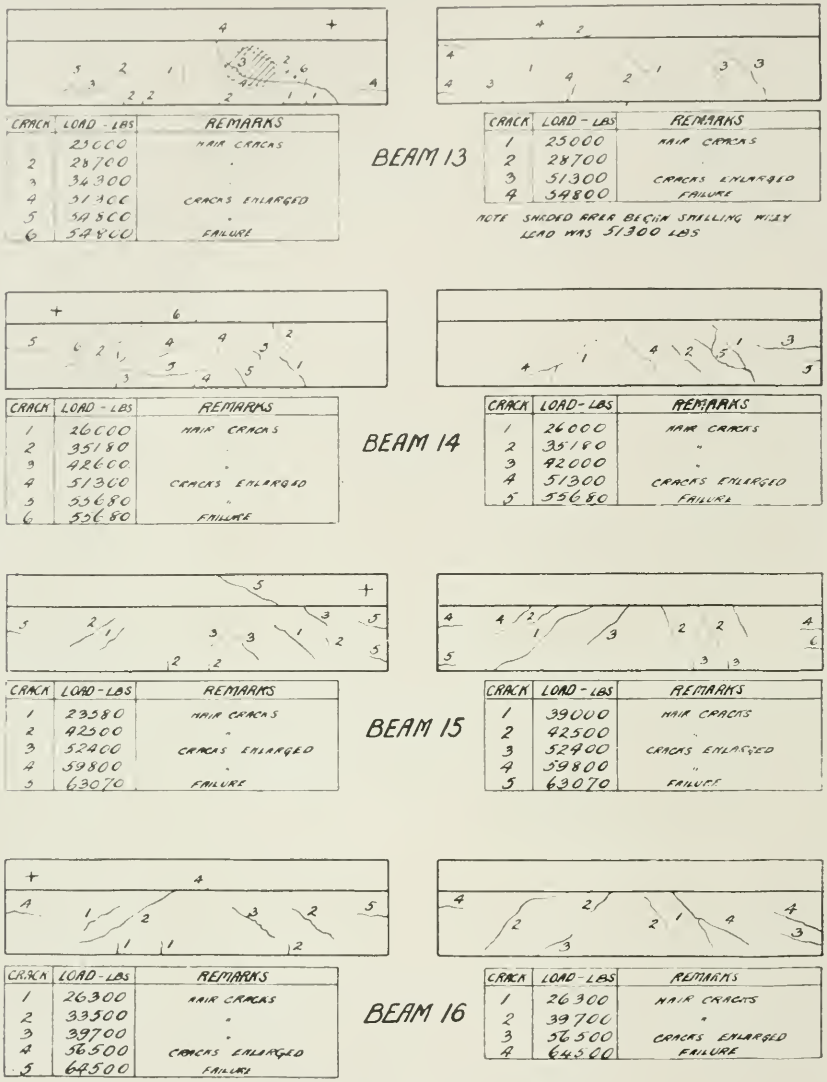
CRACK	LOAD - LBS	REMARKS
1	22500	HAIR CRACKS
2	44000	"
3	54000	CRACKS ENLARGED
4	66500	FAILURE

+ INDICATES PART OF BEAM SHOWN IN PHOTOGRAPH

FIG 46

About the R.I.B.A. results, it is curious that they give results as concordant as they do. It will be noticed that they ascribe a large value in all the beams to diagonal tension, although the fact that diagonal cracks occurred long before failure even in beams 1 and 2 proves that this had been destroyed, as theory indicates.

It must, therefore, be admitted that the concordance of the R.I.B.A. results is due to the fact that in this series the value they ascribe to diagonal tension is not so very different to the actual value of the inclined compression which actually existed.



BEAM 13

CRACK	LOAD - LBS	REMARKS
	25000	HAIR CRACKS
2	28700	"
3	34300	"
4	51300	CRACKS ENLARGED
5	54800	"
6	54800	FAILURE

CRACK	LOAD - LBS	REMARKS
1	25000	HAIR CRACKS
2	28700	"
3	51300	CRACKS ENLARGED
4	54800	FAILURE

NOTE SHADED AREA BEGAN SHELLING WHEN LOAD WAS 51300 LBS

BEAM 14

CRACK	LOAD - LBS	REMARKS
1	26000	HAIR CRACKS
2	35180	"
3	42600	"
4	51300	CRACKS ENLARGED
5	55680	"
6	55680	FAILURE

CRACK	LOAD - LBS	REMARKS
1	26000	HAIR CRACKS
2	35180	"
3	42000	"
4	51300	CRACKS ENLARGED
5	55680	FAILURE

BEAM 15

CRACK	LOAD - LBS	REMARKS
1	23580	HAIR CRACKS
2	42500	"
3	52400	CRACKS ENLARGED
4	59800	"
5	63070	FAILURE

CRACK	LOAD - LBS	REMARKS
1	39000	HAIR CRACKS
2	42500	"
3	52400	CRACKS ENLARGED
4	59800	"
5	63070	FAILURE

BEAM 16

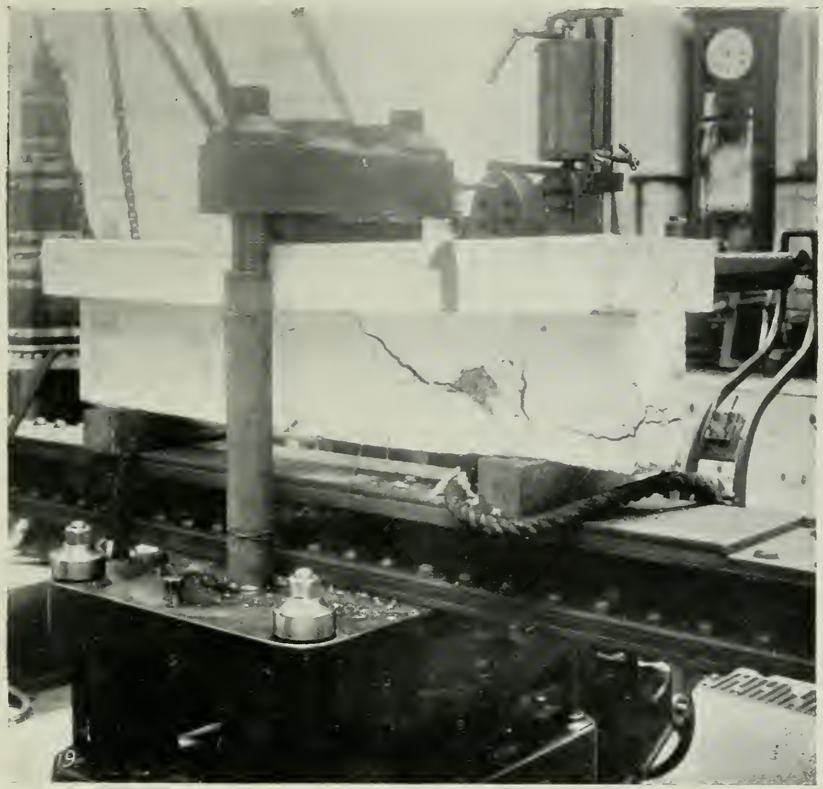
CRACK	LOAD - LBS	REMARKS
1	26300	HAIR CRACKS
2	33500	"
3	39700	"
4	56500	CRACKS ENLARGED
5	64500	FAILURE

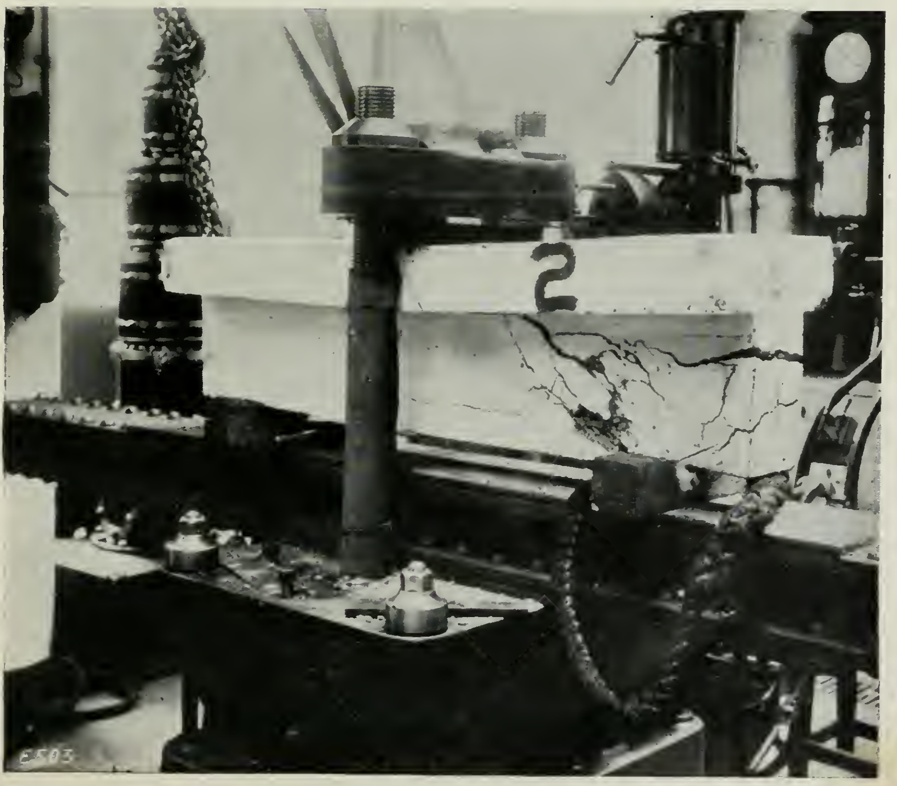
CRACK	LOAD - LBS	REMARKS
1	26300	HAIR CRACKS
2	39700	"
3	56500	CRACKS ENLARGED
4	64500	FAILURE

+ INDICATES PART OF BEAM SHOWN IN PHOTOGRAPH

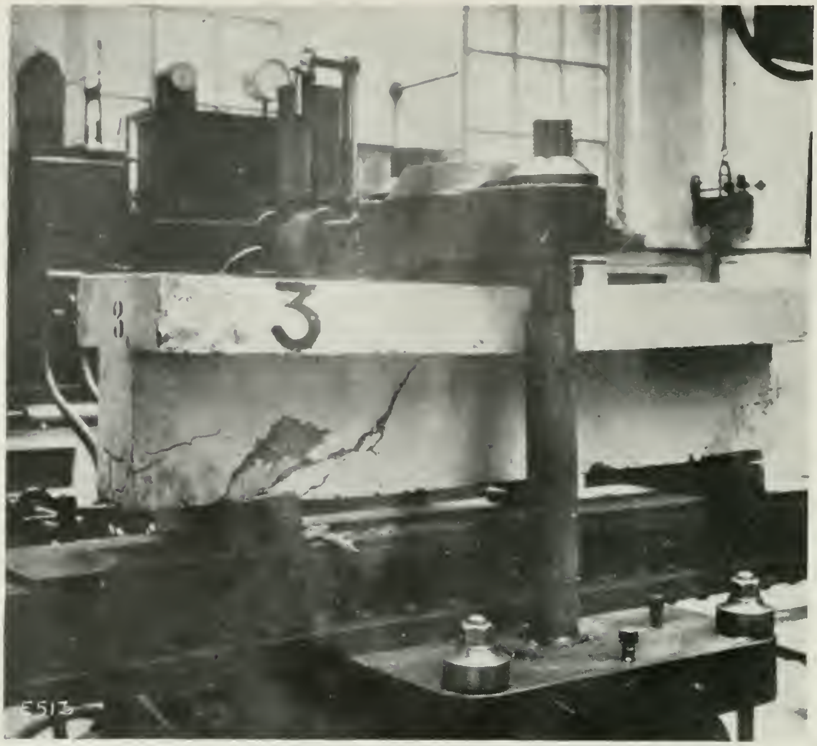
FIG. 47

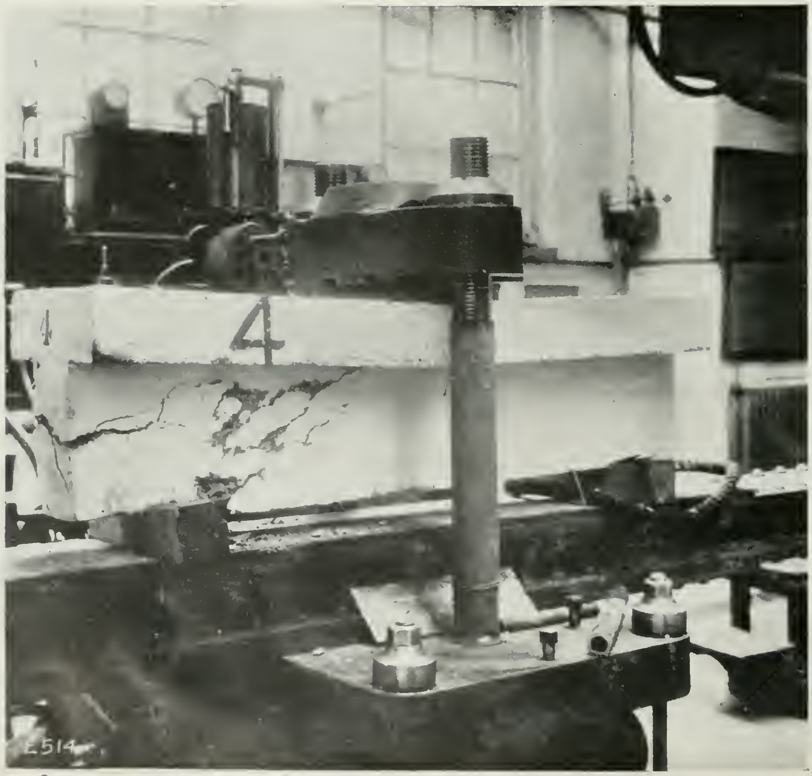
It must be noted, however, that in long beams they would still ascribe to it the same value even in combination with shear reinforcement, although the value of the inclined compression would then be very much smaller, and in such cases the R.I.B.A. method of design would lead to dangerous results by allowing for a large diagonal tension in circumstances when it could not possibly exist.



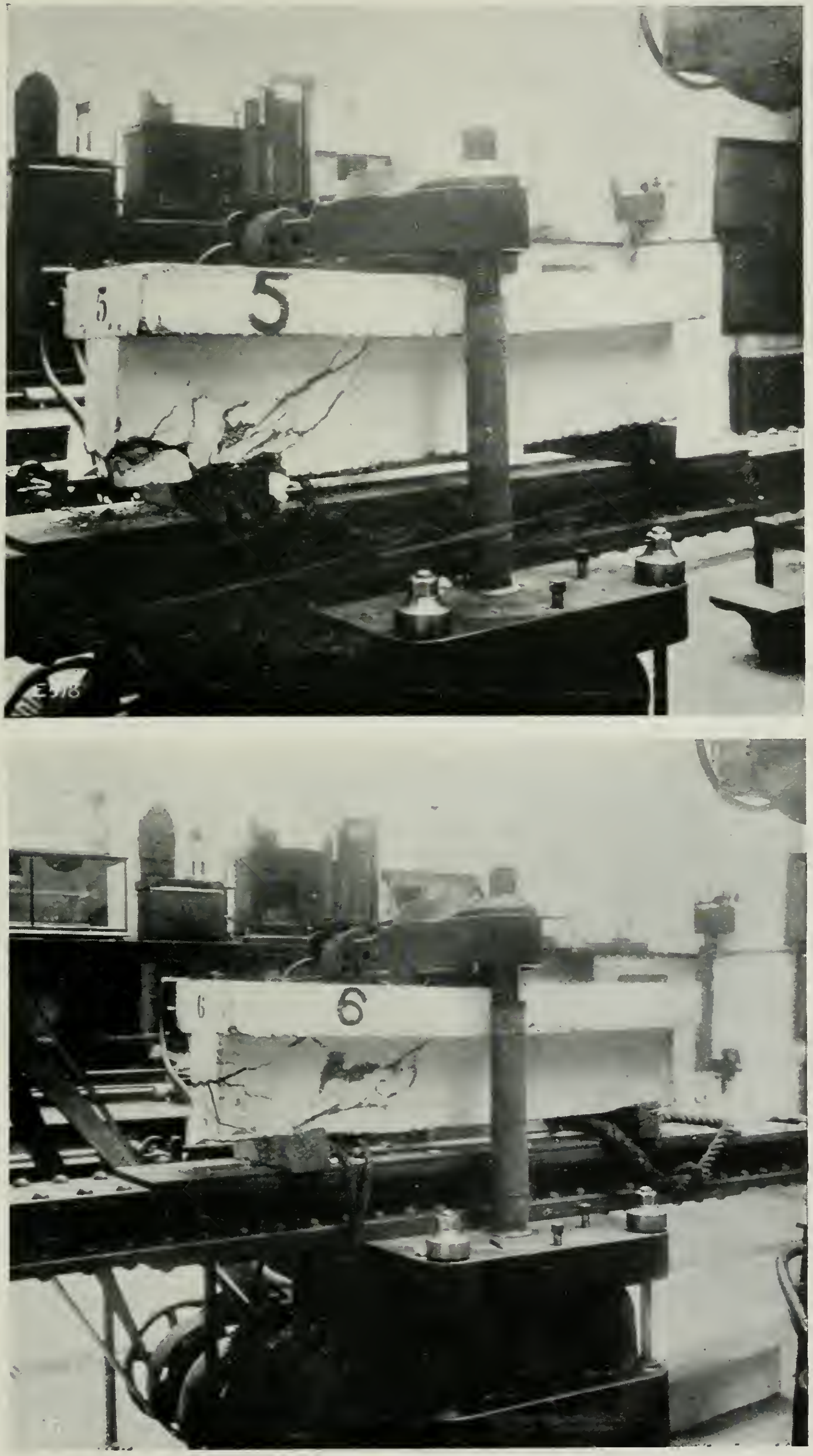


Figs. 48 and 49.

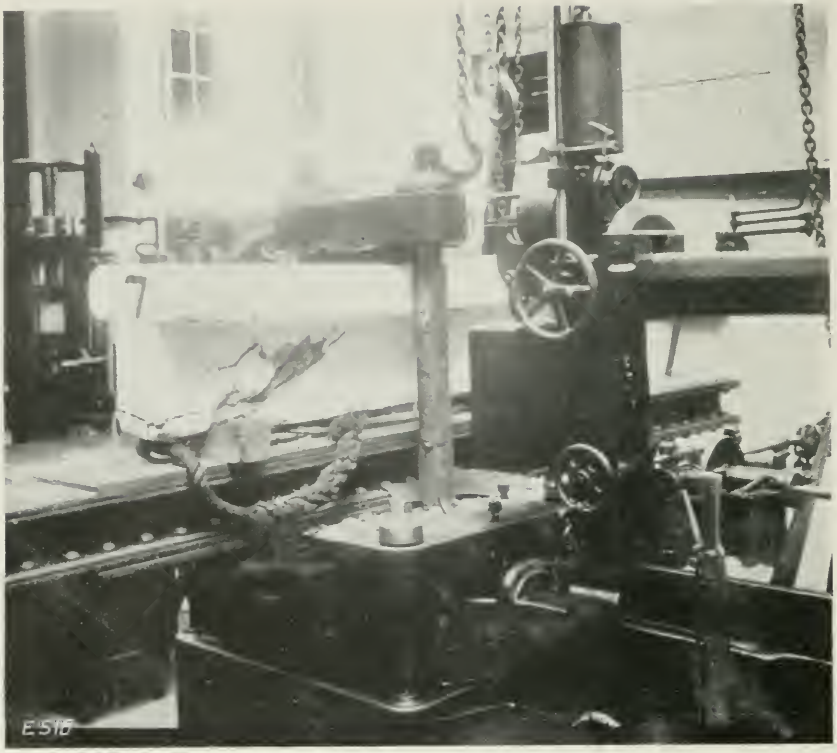


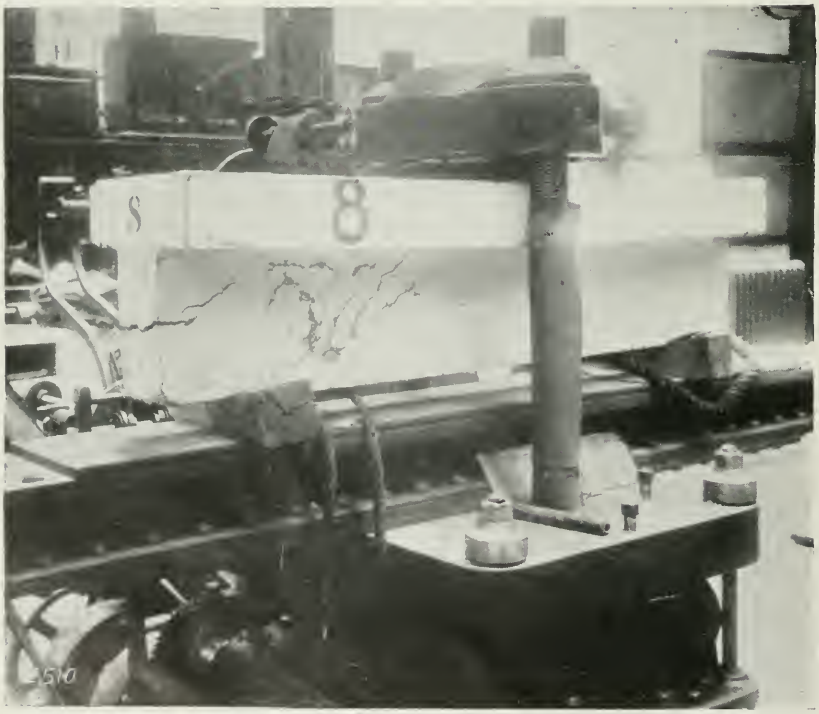


FIGS. 50 AND 51.

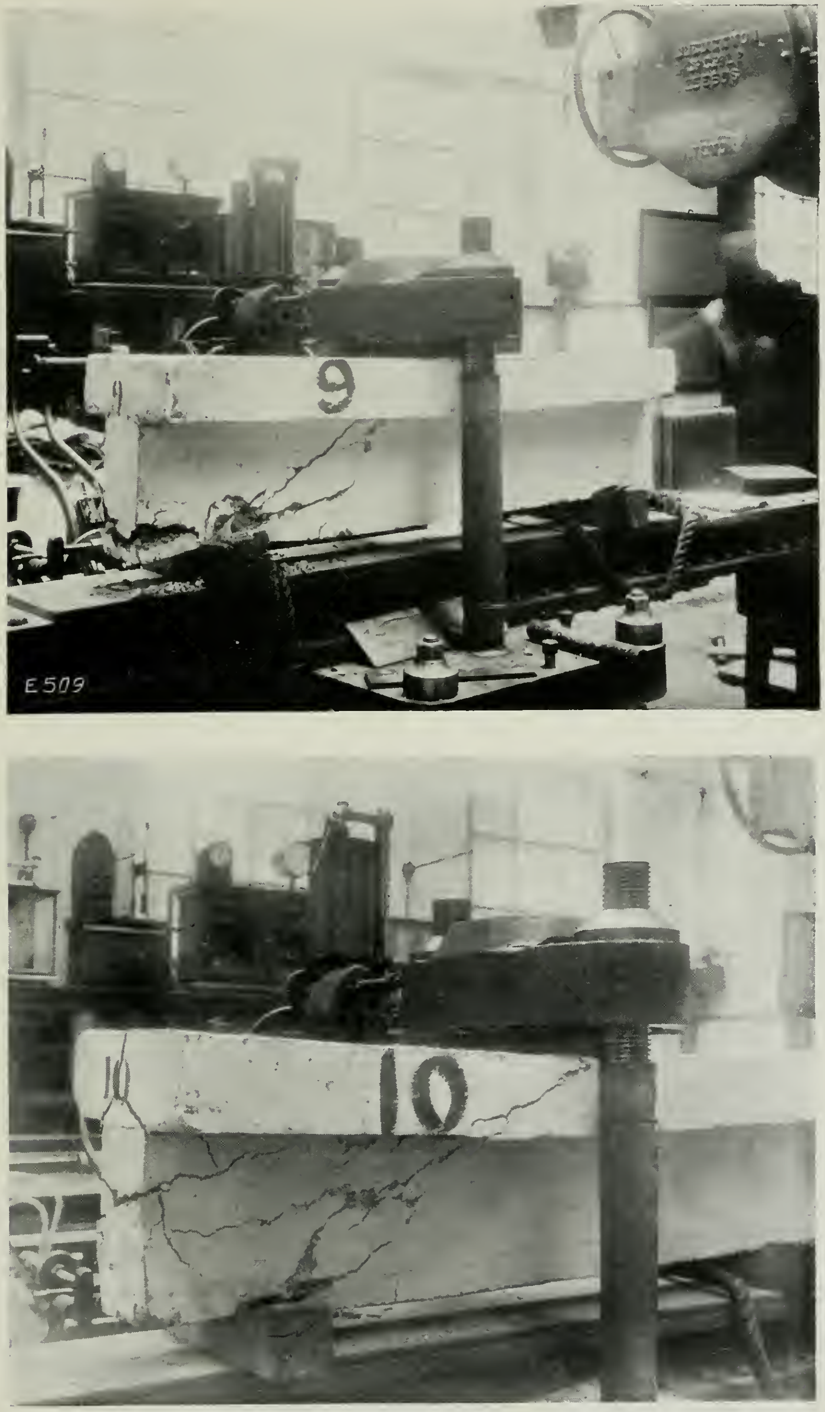


Figs. 52 and 53.

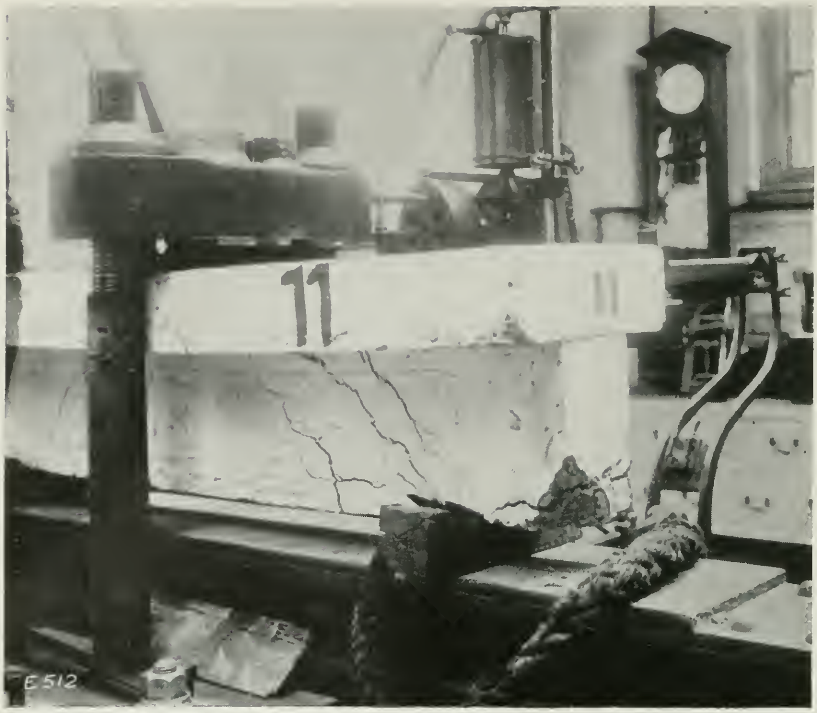


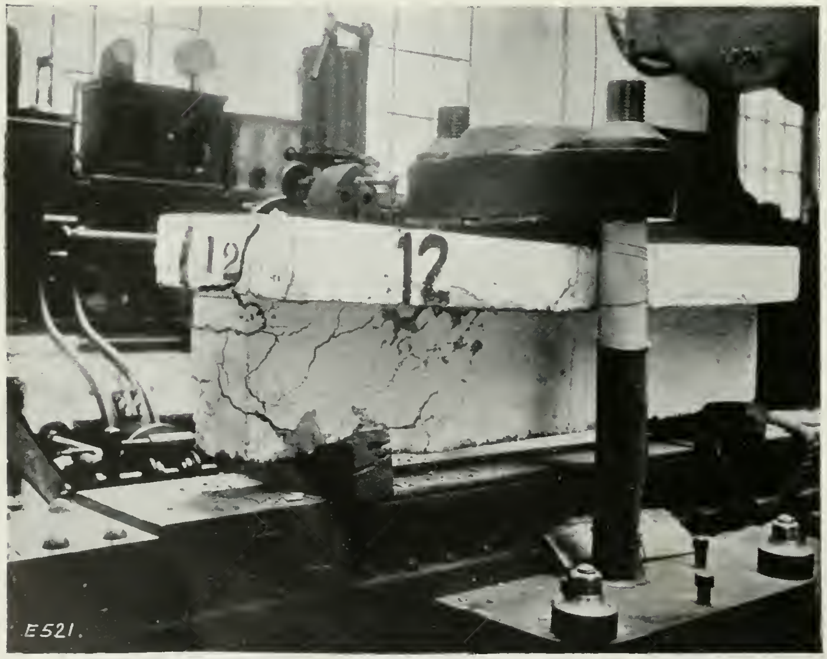


Figs. 54 and 55.

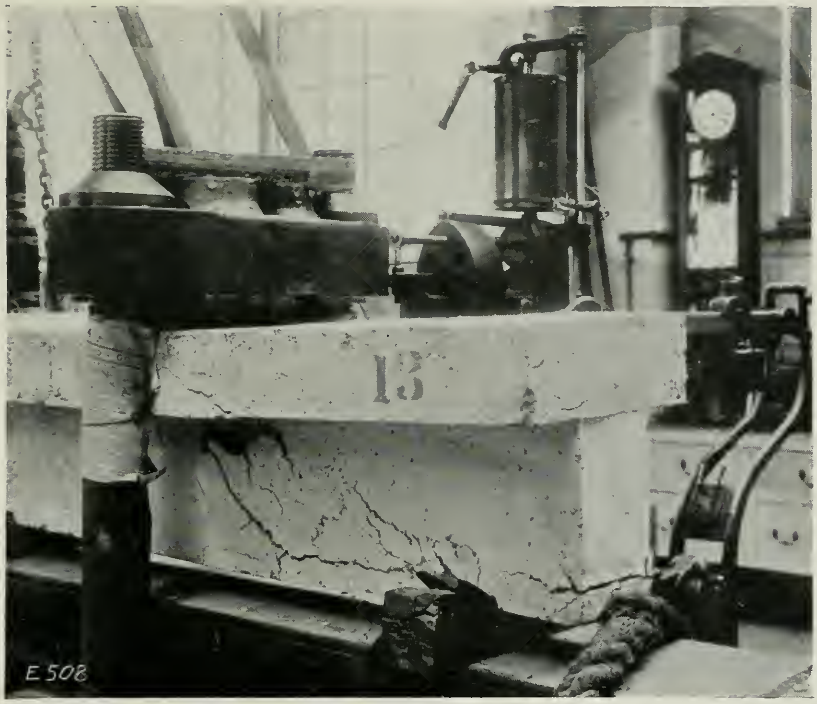


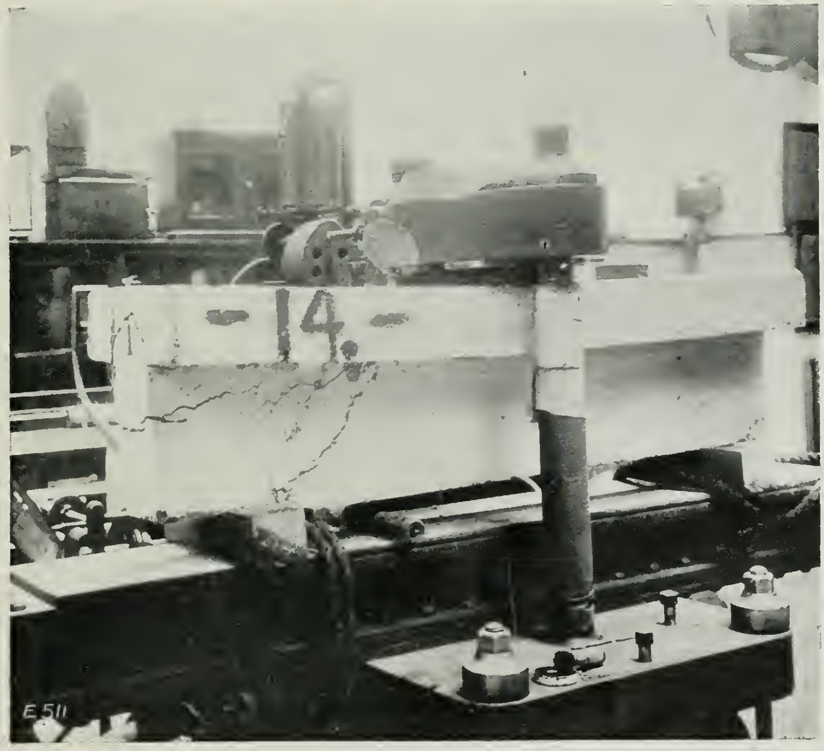
FIGS. 56 AND 57.



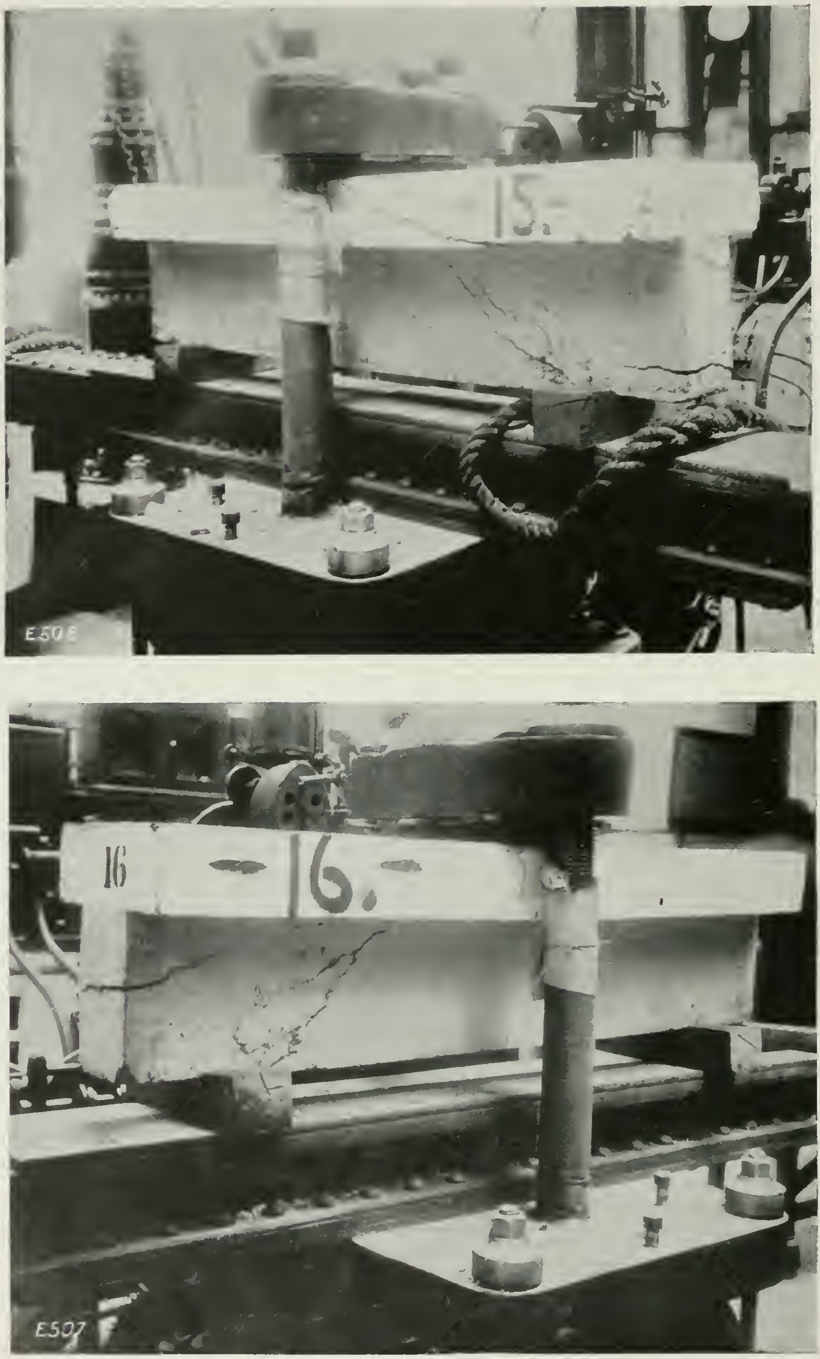


FIGS. 58 AND 59.





Figs. 60 and 61.



Figs. 62 and 63.

The results show clearly how wasteful the L.C.C. rules are, which one is tempted to ascribe to the well-known attitude of the Local Government Board to reinforced concrete. Factors of safety of 8 are luxuries that we can ill afford in these times, or, indeed, in any times.

It is interesting now to compare the loads on the beams with fishtails with those with hooks as follows :—

Fishtails.	Hooks.
42,400	47,600
54,850	50,000
50,000	48,500
56,800	52,600
41,150	56,800
57,800	66,500
54,800	55,680
63,070	64,500
420,870	442,180

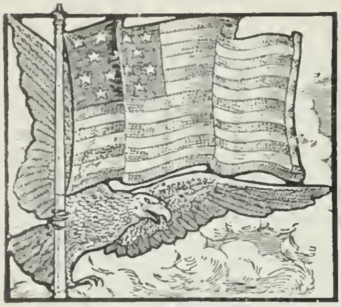
This agreement indicates clearly that failure did not occur by insufficient fixing at the support, since it would then have been too curious a coincidence that the fishtails should have the same value as the hooks.

As little information about the value of hooks and fishtails exists, it is interesting to note that the horizontal component of the inclined compression (calculated) was 13,700, and must have equalled $13{,}700 \times 3\cdot6 = 49{,}500$ lb. in beam 2, since beam 2 gave a true factor of 3·6.

Subtracting from this the friction due to the vertical reaction of 23,800 lb., which we may take equal to 11,900 (putting $\mu = 0\cdot5$) leaves a force of 37,600 lb. actually carried by the hook, corresponding to a stress in the steel of $\frac{37{,}600}{6 \times 3} = 21{,}000$ lb/in.^{2}.

We do not know whether the hooks would have carried more, but we do at least know that they carried so much.

The constancy of the writer's factors for beams 1 to 8 is specially interesting, as these are cases of superimposed inclined compressions. The author can offer no explanation why beams 13 and 14, which give the lowest factors, should have done so.



CONCRETE ROADS IN AMERICA.—OVER 3,000 MILES LAID IN THE PAST TWO YEARS.

A Review of the Papers presented at the Second National Conference on Concrete Road Building, held in Chicago in February, 1916.

By W. MATTHEWS-JONES, M.Inst.M. & Cy.E.

City Surveyor and Engineer of Chester.

Concluded from last issue. We draw especial attention in this concluding article to the tabulated comparative costs of various types of roads as compared with concrete.—ED.

CONCRETE PAVEMENTS IN SUBURBAN AND RURAL DISTRICTS.

THE paper presented by Eugene W. Stern, Chief Engineer of the Highways Borough of Manhattan, New York, on "The Use of Concrete Pavements in Suburban and Rural Districts near Large Cities," gives one much food for thought. He deals very concisely with the cost and maintenance of roads, and shows the advantages to be derived from good roads. He points out how rapidly a district will grow after these have been made, and in referring to Wayne County, Michigan, he says that land used for farming purposes could be bought for less than $200 an acre within a reasonable distance of Detroit, but after good roads were constructed (presumably of concrete) such land was so enhanced in value within a short time that it was sold for $1,200 an acre. He also states that the assessed valuation has increased from $62,000,000 in 1906 to $136,000,000 in 1915, and in the last year alone the increase was $22,000,000, or 20 per cent.

This, in my opinion, speaks volumes in praise of concrete road construction, because we know that Wayne County may truly claim to be one of the pioneers in this work, and here is a case where the ends have justified the means.

Mr. Stern admits that water-bound and bituminous macadam roads go to pieces very rapidly and cost a great deal for upkeep under even moderate traffic, and, further, he states: "We must therefore attack this problem with skill and an open mind, as mistakes are now proving very costly to the community; and the construction of bad types of roads will place enormous burdens on the taxpayers in the years to come."

I now quote what he considers the essentials of a good road. It should be:—

1. Sanitary.
2. Safe for public travel.
3. Possess a hard, smooth surface under all conditions of weather and at all times of the year.
4. Not be too slippery for horses, and, of course, must be thoroughly adapted to motor vehicles.
5. Have a reasonable first cost and also a low cost of maintenance, coupled with ease of repair; in other words, the annual charges against the pavement, including amortization, interest on the money invested, and maintenance should be as low as possible.

Types of Road.—Then he goes on and reviews the subject of the selection of a proper type of road, and makes the following observations:—

"While the subject assigned me was the "Possibilities of Concrete Highways," it will be of interest to analyse briefly the merits and demerits of the various well-known types of roads with which the highway engineer has had experience in recent years. It is my opinion that there is not much necessity for further experimenting to decide as to suitable types, as ample experiences are already available, particularly if we carefully scan the recent information collected by the cities throughout the country, and compare it with that from the rural districts. It is almost unbelievable that many country highways cost the ratepayer much more than city pavements having many more times the amount of traffic. While there is no uncertainty about the first cost, there is some difficulty, however, in properly arriving at the maintenance cost. The most approved types of highways have been in common use for a short time only, and motor traffic is very recent; and while we know a good deal as to their durability under present conditions, we must look ahead and try to foretell how long their life will be and what the probable cost of maintenance over their period of years will be. I hope, however, that the figures which I am about to present will be thoroughly discussed, and as a result that we may have authoritative data made available. Let us now consider the following well-known types of roads and pavements:—

Concrete.
Bituminous concrete on concrete base.
Sheet asphalte on concrete base.
Brick on concrete base.
Bituminous macadam on gravel or broken stone base.
Asphalte block on concrete base.
Water-bound macadam.
Wood block on concrete base.
Granite block on concrete base.

"In order to arrive at a basis for comparison, let us reduce all these various types to a gross annual cost per square yard, which includes interest on first cost, plus amortization, plus annual repairs. I have taken the country district immediately about New York as a basis for comparison as to cost, and therefore, of course, the figures of first cost given below must be modified to suit local conditions. In some districts, for instance, such as Worcester, Mass., a granite pavement can be laid with cement grouted joints and with concrete base for as low as $3.10 a square yard, with an annual maintenance cost averaged for fifteen years of only 6/10 cent a square yard. There are places in the middle west where a brick pavement can be laid for considerably less.

"As regards maintenance costs, I have taken the figures for recent years only, because the farther back one goes, the farther we get away from present conditions."

We now come to his statement as to comparative cost of various kinds of roads, and I think it would be unwise if I did not quote his very interesting figures:—

Comparative Cost of various Kinds of Road.

CONCRETE.

Assumptions.—Useful life at 20 years as a wearing surface; after which to be used as foundations for a wearing surface such as bituminous concrete, sheet asphalte, asphalte block, etc.

	Per sq. yd.
Cost of concrete pavement 6 in thick...	$1.12
Value as a foundation ...	.80
Cost of wearing surface—20-year life...	$0.32

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement $1.12 at $4\frac{1}{4}\%$ ...	4.76
Amortization on wearing surface 32 cents at $3\frac{1}{4}\%$ ...	1.04
Annual repairs ...	2.00
Total cost ...	7.80

ASPHALTIC OR BITUMINOUS CONCRETE.

2½ in. thick on 6-in. concrete base.

Assumptions.—Useful life of wearing surface 20 years; top 2½ in. thick; Borough of Bronx specifications.

	Per sq. yd.
Cost of concrete base 6 in. thick	$0.80
Cost of wearing surface 2½ in. thick	.70
Total	$1.50
Annual repairs	2.35 cents

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement $1.50 at 4¼%	6.375
Amortization on top, 70 cents at 3¼%	2.275
Annual repairs	2.35
	11.00

SHEET ASPHALTE

3 in. thick on 6-in. base.

Assumptions.—Useful life of wearing surface 25 years, top 3 in. thick; Borough of Manhattan specifications.

	Per sq. yd.
Cost of concrete base 6 in. thick	$0.80
Cost of wearing surface 3 in. thick	.90
Total	$1.70
Annual repairs	2 cents

Gross Annual Cost per Square Yard.

	Cents.
Interest charged on pavement $1.70 at 4¼%	7.225
Amortization on top, 90 cents at 2¼%	2.025
Annual repairs	2.00
Total	11.25

BRICK.

4 in. thick on concrete base.

Assumptions.—Useful life of wearing surface 25 years.

	Per sq. yd.
Cost of wearing surface (N.Y. States)	$1.20
Cost of 6-in. concrete base	.80
Total	$2.00
Annual repairs	2 cents

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on payment $2.00 at 4¼%	8.5
Amortization on top, $1.20 at 3¼%	3.9
Annual repairs	2.0
Total	14.0

BITUMINOUS MACADAM.

	Per sq. yd.
Cost of pavement	$0.871
Annual repair of pavement	.121

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement, $0.871 at 4¼%	3.7
Annual repairs	12.0
Total	15.7

ASPHALTE BLOCK.

2½ in. thick on 6-in. concrete base.

Assumptions.—Useful life of 2½ in. wearing surface 20 years.

	Per sq. yd.
Cost of wearing surface	$1.40
Cost of concrete base 6 in. thick	.80
Total	$2.20
Annual repairs	3 cents

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement, $2.20 at 4¼%	9.35
Amortization on wearing surface, $1.40 at 3¼%	4.55
Annual repairs	3.00
Total	16.9

WATER-BOUND MACADAM.

Assumptions.—

	Per sq. yd.
Cost of pavement	$0.648
Annual repairs	.15

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement, 64.8 cents at 4¼%	2.75
Repairs	15.00
Total	17.75

WOOD BLOCK.

3 in. thick on 6-in. concrete base.

Assumptions.—Useful life of wearing surface 20 years.

	Per sq. yd.
Cost of wearing surface	$2.00
Cost of concrete base 6 in. thick	.80
	$2.80

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement, $2.80 at 4¼%	11.90
Amortization on wearing surface, $2.00 at 3¼%	6.50
Annual repairs	2.00
Total	20.4

GRANITE BLOCK.

4 in. thick on 6-in. concrete base.

Assumptions.—Useful life of wearing surface 35 years.

	Per sq. yd.
Cost of wearing surface	$3.00
Cost of 6-in. concrete base	.80
Total	$3.80
Annual repairs	1 cent

Gross Annual Cost per Square Yard.

	Cents.
Interest charge on pavement, $3.80 at 4¼%	16.15
Amortization on wearing surface, $3.00 at 1.28%	3.85
Annual repairs	1.00
Total	21.0

The following shows the gross annual cost per square yard, which includes interest on first cost, plus amortization, plus annual repairs:—

Kind.	Annual cost per sq. yd. in cents.
1. Concrete	7·8
2. Asphaltic concrete on 6-in. concrete base	11
3. Sheet asphalte on 6-in. concrete base	11·25
4. Brick on 6-in. concrete base	14
5. Bituminous macadam	15·7
6. Asphalte block	16·9
7. Water-bound macadam	17·75
8 Wood block	20·4
9 Granite block	21

"From the above we see that the concrete pavement costs 7·8 cents per square yard per year, and that next to this asphaltic concrete costs 11 cents per square yard per year, or about 40 per cent. more; bituminous macadam 15·7 cents per square yard, or double as much; and water-bound macadam 17¾ cents per square yard, or over 2¼ times as much."

I might add here that my experience of maintenance cost of the concrete roads I have laid, extending over a period of eight years to the present, has been practically nil as compared with other classes of road surfaces.

I cannot do better in closing my notes on Mr. Stern's paper than quote the questions and answers given during the discussion on it :—

MR. STERN.—I am hoping that the figures I have given will be challenged in order that a discussion may bring out more facts. They show that the concrete pavement costs the taxpayer less than one-half that of the water-bound macadam road to perpetuate. It is startling, to say the least, to realise that we can have a thoroughly first-class highway, good for twelve months in the year, which answers all the requisites of a city pavement, which is clean, dustless, smooth, comfortable for traffic, for one-half of what a country highway will cost which is broken up part of the year and is more or less dirty and uncomfortable.

As I have stated before, the concrete highway acts both as a foundation and as a wearing surface.

In order to renew the wearing surface I have assumed, in my calculations, its life as such to be 20 years and have provided a sinking fund for it, so that my figures show what it would cost the taxpayers per year to perpetuate the pavements, and this is the only way to estimate the cost of any public improvement.

MR. J. KUELLING.—Do you include the cost of sinking fund beyond that?

MR. STERN.—No. The sinking fund is provided only for the wearing surface, as the pavement should last as a base for as much even as 75 years if the foundation is properly made and drained, and the pavement is not cut into frequently. Hence the sinking fund charge on the concrete pavement using it as a base, will be so small as to be negligible.

MR. F. F. GOSS.—We have been highly entertained by this talk, but the weakest point in concrete is the strongest point, and that is the ease and rapidity with which it can be cut through and be repaired.

A MEMBER.—What is the average cost of a one-course concrete pavement 6 in. thick?

MR. STERN.—The average cost is $1.12 per sq. yd. around New York City, Westchester County, and Connecticut.

MR. C. WHITING BAKER.—Some gentlemen think an annual maintenance cost of $180 per mile for concrete pavement is high.

MR. STERN.—I submit that I also stated it is high. I am commencing, however, with no maintenance charge the year it is built, and ending at the end of twenty years with 4 cents a yard per year. I am conservative purposely, because I do not want it said that I am biased in favour of any particular kind of pavement. My object in placing this diagram before you is to show what I arrived at as the reasonable expectancy for the next twenty years. I am assuming that travel is going to increase over these concrete highways as it is now increasing.

CONCLUSION.

This closes my remarks on the various papers submitted to the Conference, but the papers read and discussed do not contain anything like the whole of the proceedings. The printed report in my hand records the work of the various committees on the subject of concrete road construction, of which 17 have been formed, each dealing with separate recommendations of constructive work, under the following headings :—

1. Drainage and preparation of sub-grade.
2. Economical widths of pavement and shoulders.
3. Problems of design, thickness, crown, and grade.
4. Aggregates for concrete roads.
5. Handling and hauling materials and water supply.
6. Organisation of concreting crew.
7. Proportions of materials and consistency of concrete.
8. Mixing and placing of concrete.

9. Reinforcement.
10. Joint location and construction.
11. Expansion and contraction.
12. Finishing and curing.
13. Construction of shoulders and curbs.
14. Methods and cost of maintenance.
15. Form of specifications for concrete roads.
16. Cost of construction.
17. Estimating and inspection problems.

The committees' deliberations are given in the proceedings, and form a very valuable part of such.

I cannot refrain from expressing my high appreciation of the go-ahead and business-like way of our brother American engineers. They have shown, in my opinion, a wide-awake policy, and have given road engineers and surveyors in this country an insight into their methods of dealing with road questions on a proper basis, such as has never been attempted by any body of professional men in England. I have during my professional career attended conferences in this country, and have spent a good deal of money on books to obtain knowledge on road construction; but I must admit that the "Proceedings of the Second National Conference on Concrete Road Building" contains more information and data than any booklet I know of. Our thanks are due to the engineers and surveyors in America for the care and foresight which has been taken in compiling such information, and also to the Secretary of the Conference, Mr. J. P. Beck, who must have spent an enormous amount of time and trouble to edit and bring into shape in such a readable manner all the interesting details.

I sincerely hope that the President and members of the Local Government Board, the chairman and members and engineers of the Roads Board, as well as engineers and surveyors to county and local authorities will, after reading the proceedings referred to, use their influence to bring together public bodies and their officials for the purpose of discussing the question of better and more permanent road construction in this country, so that some standard can be formed and fixed for engineers and surveyors to work to, and any help I can give or information will be gladly placed at their disposal.

My final word to the public generally is to agitate for good sanitary and durable roads, and they must not rest until their object has been achieved. Haulage contractors, motor 'bus and motor-car owners, horse owners, and all people who use the roads, not only for pleasure, but for business purposes, must make up their minds to form associations, such as is done in America, and which are called "Good Road Associations," and so bring their views before the local authorities and their officials.

(In our next issue we hope to publish an article on some Experimental Reinforced Concrete Road Construction in Australia and New Zealand.)

RECENT VIEWS ON CONCRETE AND REINFORCED CONCRETE.

Recent Papers and Discussions.

It is our intention to publish the Papers and Discussions presented before Technical Societies on matters relating to Concrete and Reinforced Concrete in a concise form, and in such a manner as to be easily available for reference purposes.—ED.

AMERICAN BUREAU OF STANDARDS.

STRENGTH AND OTHER PROPERTIES OF CONCRETES AS AFFECTED BY MATERIALS AND METHODS OF PREPARATION.

By R. J. WIG, Engineer Physicist; G. M. WILLIAMS, Assistant Engineer Physicist; and E. R. GATES, Assistant Physicist, Bureau of Standards.

The following abstracts and illustrations are reproduced from Technologic Paper No. 58 of the Bureau of Standards, U.S.A. :—

A REPORT of some considerable importance and interest has been issued by the Bureau of Standards, U.S.A., under the above title. The report is a most comprehensive one, and it would be quite impossible to reproduce it at all fully. As will be seen from the following abstracts given, the results of some 20,000 tests are included in the paper. A large number of diagrams are given, and we have reproduced one or two of these.

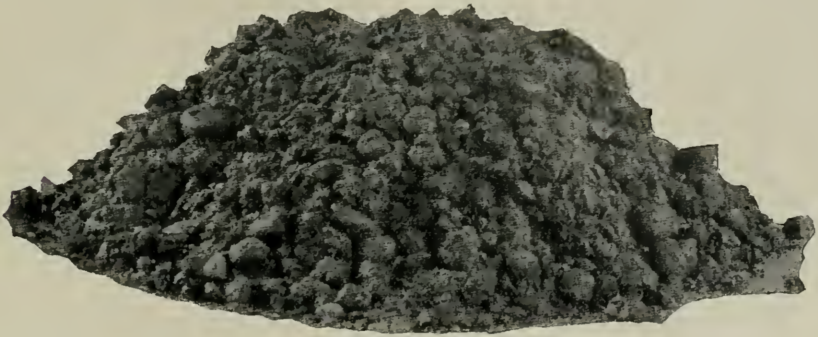
INTRODUCTION.

Concrete differs from most structural materials in that it is not manufactured at a mill or plant according to chemical formulæ under the observation of skilled specialists and subject to rigid inspection, test, and such control as to produce a uniformly homogeneous product, nor is the process of manufacture completed in a few hours or days, as in the case of steel products. Furthermore, concrete is made from materials obtained from many sources differing widely in characteristics which affect its quality. The proportions of the ingredients, the amount of water used in mixing, the thoroughness of mixing, the manner of placing, the atmospheric temperature and humidity, exposure to sun, rain, and wind, immersion in fresh water, sea water, or other natural solutions—all affect the quality of the concrete.

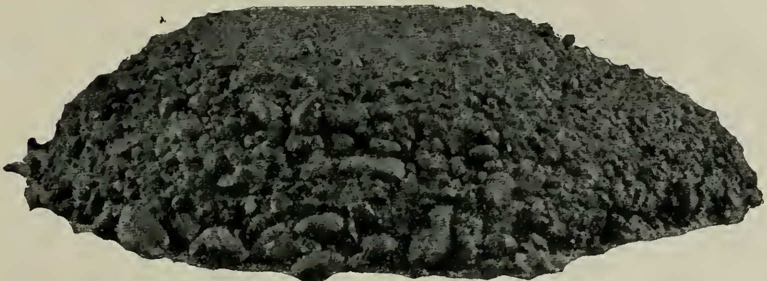
The quality of structural steel can be determined easily and quickly at the place of manufacture and the strength of a fabricated structure is readily calculated. The physical qualities of the metal are unchanged during erection, provided good practice in design and construction have been followed, and the strength of the completed structure is directly dependent upon the strength of the steel as originally determined.

In most cases the inspection of the materials which are used to fabricate concrete is confined to tests of the cement, although the strength of a structure made of concrete can be no more completely determined by inspection of the cement than can the strength of structural steel be measured by an analysis of the iron ore from which the steel is to be made. Concrete made with cements of standard quality but with different aggregates may, in one case, have considerable strength and, in another, practically no strength. With the same cements and aggregates but with different workmanship in fabrication one concrete may have several hundred per cent. greater strength than another. Concretes which are permitted to dry permanently from the time of mixing will never attain the strength of concretes of similar mixture which are supplied with water from time to time after mixing.

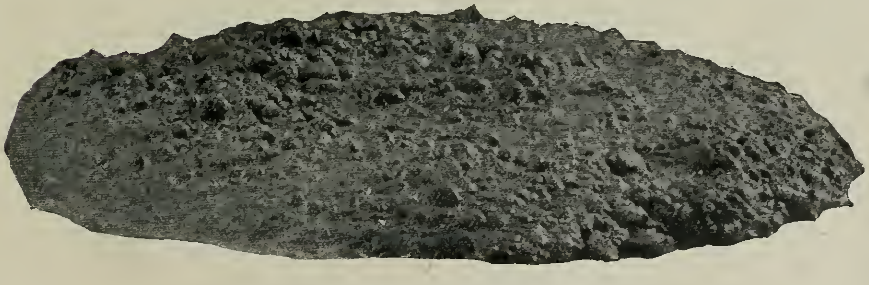
The principal requisites for a concrete aggregate are cleanliness, strength, homogeneity of structure, and proper gradation of particles. The relative values of these variables are difficult to determine and may not be the same in any two cases.



Quaking Consistency.



Mushy Consistency.



Fluid Consistency.

FIG. 1. APPEARANCE OF GRAVEL CONCRETE OF THE THREE CONSISTENCIES USED IN THESE TESTS AND DESCRIBED ON PAGE 614.

The greatest value of this paper, perhaps, is in emphasising the necessity of having a knowledge of all the materials used in fabricating concrete, and the necessity of exercising extreme care in every phase of the manufacture of concrete, if the good quality of the resulting concrete is to be assured and a concrete of known quality produced.

The paper includes the results of about 20,000 tests. Compressive and tensile tests were made upon mortars at different ages, including about 240 different sands and stone screenings, and compressive tests were made on concretes composed of sixty aggregates, including limestones, gravels, granites, cinders, and trap rock, as well as tests of the physical properties of the sands, stone screenings, and coarse aggregates.

The consistencies of concrete referred to throughout this paper from the driest to the wettest may be defined as follows :—

Dry.—Containing just sufficient water to cause the cement and sand to adhere after tamping and removal of the moulds.

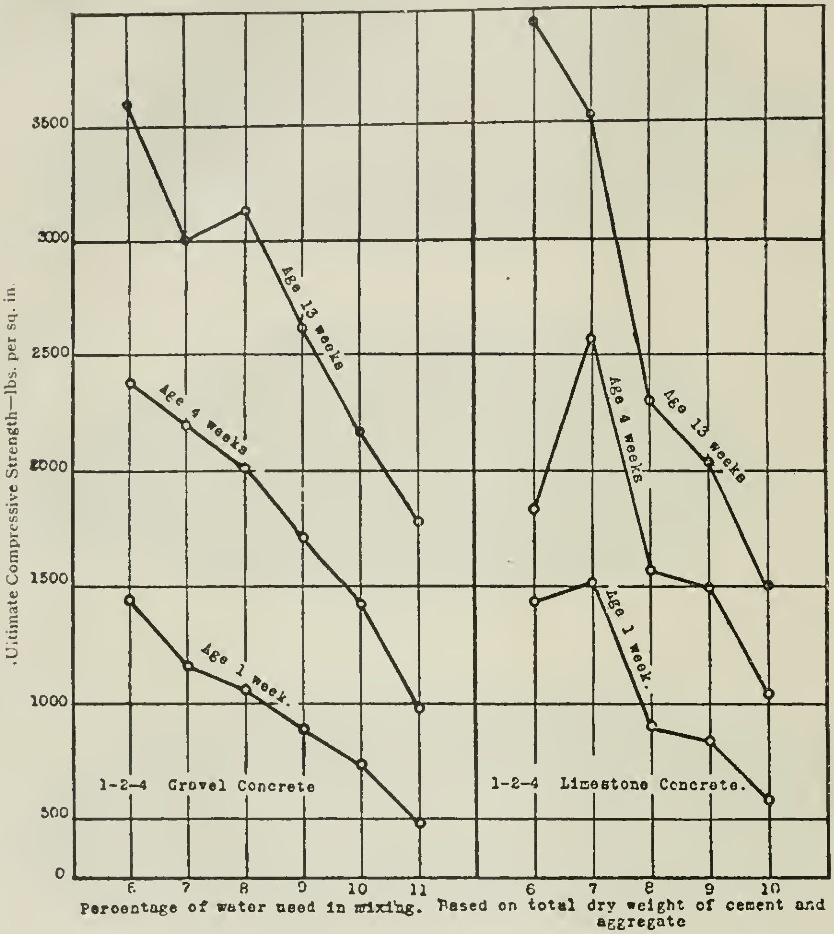


Fig. 2. Relation of Consistency of Mixtures of Portland Cement Concretes to the Compressive Strength. (Test Pieces, 8 by 16 in. Cylinders.)

Moist.—A mean between the "dry" and "plastic" consistencies.

Plastic.—Containing the maximum quantity of water which allows the removal of the forms immediately after moulding. The surface of the mass shows weblike marks of neat cement and water.

Quaking.—A stiff mixture upon which water can be brought to the surface by slight tamping. The mass should not flow readily.

Mushy.—A soft mushy mixture which is not watery, but can be spaded and readily worked into place in the form.

TABLE 2.

Compressive Strength of Portland Cement Mortars, showing Effect of Variation in the Proportions of Cement to Fine Aggregate and Variation in Consistency of Mixture.

(All results are the average of 3 or more tests of 8 by 16-in. cylinders.)

Materials.	Proportion by volume 1 : 2 (ultimate stress, lb. per sq. in.)				Proportion by volume 1 : 3 (ultimate stress, lb. per sq. in.)						Proportion by volume 1 : 4 (ultimate stress, lb. per sq. in.)						Proportion by volume 1 : 8 (ultimate stress, lb. per sq. in.)			
	Per cent. mixing water	28 days	3 mon.	6 mon.	Per cent. mixing water	7 days	28 days	3 mon.	6 mon.	1 year	Per cent. mixing water	7 days	28 days	3 mon.	6 mon.	1 year	Per cent. mixing water	28 days	3 mon.	6 mon.
Typical Portland cement and sand 181 ..	*6.5 †9.0 ‡10.5	917 2,194 3,416	1,374 2,726 3,180	1,595 2,866 3,512	— — —	— — —	— — —	— — —	— — —	— — —	*5.5 — —	— — —	751 1,137 1,854	929 1,670 2,286	1,074 1,584 2,342	 — —	*4.5 †6.5 ‡8.0	302 589 545	433 828 900	506 872 838
Typical Portland cement and sand 186 ..	—	—	—	—	13.3	—	1,290	2,063	2,450	—	12.8	—	838	1,346	1,425	—	—	—	—	—
Typical Portland cement and limestone screenings ..	—	—	—	—	17.0	1,808	2,766	3,600	3,792	4,275	16.0	1,317	2,041	2,530	3,017	3,308	—	—	—	—

* Dry consistency. † Moist consistency. ‡ Plastic consistency.

FLUID.—A watery mixture which flows readily into place in the form with little or no working.

A photograph of three batches of concrete to illustrate the three consistencies—"quaking," "mushy," and "fluid"—are shown on p. 613. In forming each of the piles the concrete was allowed to slide from the shovel and drop only a few inches on to the pile, the weight causing the material to spread out and take the shapes shown. Dumping from a barrow, or allowing the mixtures to flow from a chute would have caused the materials to spread further and form flatter cones, which would give the appearance of wetter consistencies than the method which was used.

(D) QUALITY AS AFFECTED BY CONSISTENCY.—The strength of a mortar or concrete, especially at the early periods, is affected to a considerable extent by the consistency or the proportion of mixing water.

The results given in Table 2 show the effect of varying the amount of water in a mortar of various proportions. In the mixture of one part cement to two parts sand there is a difference in strength at twenty-eight days between the plastic and dry consistencies of 2,499 pounds, or 275 per cent., while at six months the difference is 1,917 pounds, or about 120 per cent.

SUMMARY.

1. Portland Cement Mortar Mixtures.—Sands as a type of fine aggregate cannot be said to be superior to limestone screenings.

The proper gradation of the fine aggregate for maximum strength in a mortar appears to vary for different materials.

The results of the tests of the mortars included in this paper would indicate that for most materials the highest strengths are obtained with those having a gradation of particles approaching a straight line. There are materials, however, which have a gradation varying widely from a straight line which give high strength in mortars.

The quality of a sand cannot be judged from its gradation alone. Any limitation arbitrarily placed upon the proportions of the particles of various sizes will probably eliminate some very satisfactory materials.

No fine aggregate should be rejected because of its "silt" content determined by washing or assuming the material passing the number 200 sieve as silt, as it may be advantageous even in relatively large quantities or detrimental in small quantities depending upon its form, character, and distribution.

Mortars having high density usually have high strength.

The quality of sands to be used in cement mortars cannot be determined from their "uniformity coefficients."

There is no difference in the strength developed by rounded and sharp-grained sands.

The quality of sands cannot be determined from their specific gravity and porosity.

The only satisfactory method of determining the value of a fine aggregate in mortar mixtures is to test it in the mixture in the proportion to be used, exposed to the same conditions as in the proposed structure.

Common usage has demonstrated that certain sands are satisfactory and, therefore, no tests of these materials are necessary excepting to identify them.

The relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the coarse aggregate.

The general effect on the compressive strength of variation of the several factors entering into the fabrication of concrete is shown graphically in the diagram on p. 617.

2. Portland Cement Concrete Mixtures.—(A) RELATION OF TYPE OF AGGREGATE TO COMPRESSIVE STRENGTH.—No type of gravel or stone aggregate can be said to be generally superior to any other type used as coarse aggregate in concrete mixtures. Certain limestones are superior to certain gravels, and some gravels are better than other limestones. The range of qualities in any of these types is very great and the strengths of concretes made up of several different materials of the same type may vary as much as several hundred per cent. with all other controllable factors uniform.

(B) RELATION OF WORKMANSHIP TO COMPRESSIVE STRENGTH.—Undoubtedly greater uniformity is generally obtained by machine mixing than by hand mixing. The method of mixing is of little importance so long as it results in a homogeneous mass. Using proper methods and with the expenditure of sufficient labour, results indicate that as good concrete can be obtained by hand mixing as by machine mixing, although it probably would not be economical.

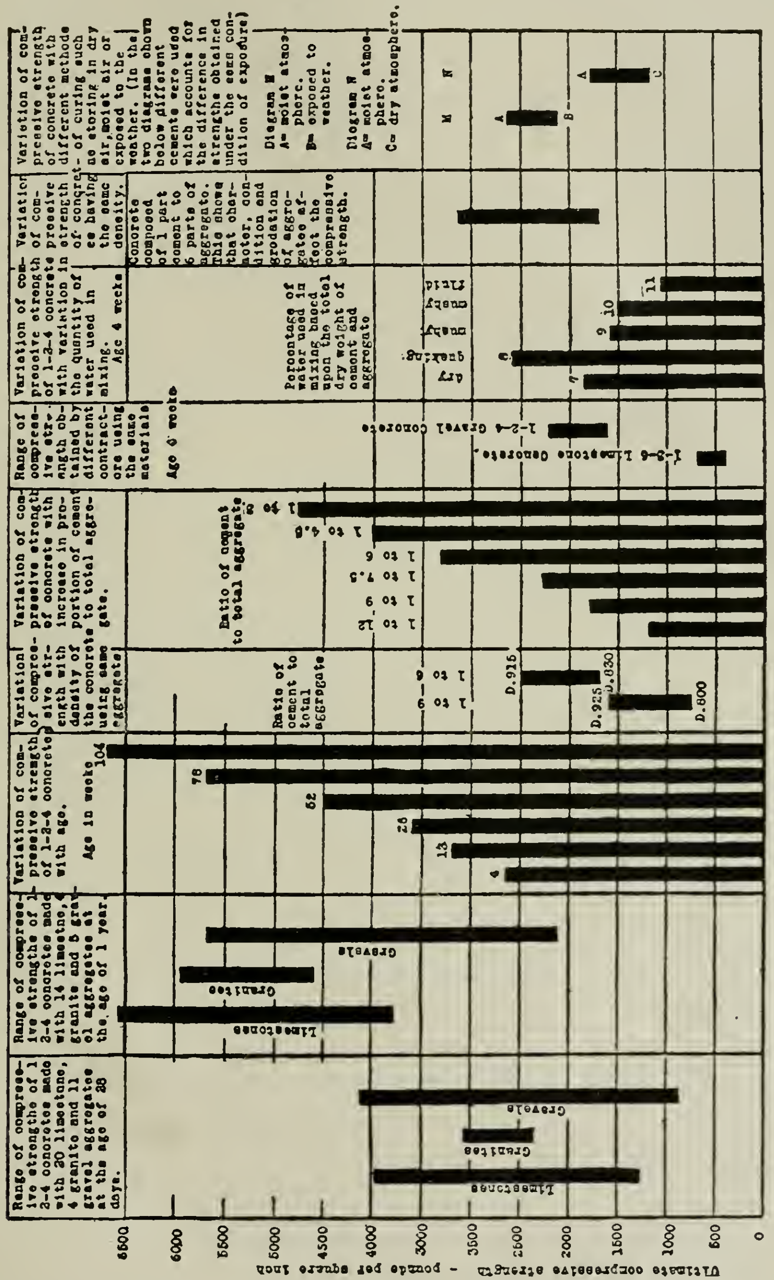


Fig. 3. Summation Diagrams showing the Range in Compressive Strength of Portland Cement Concretes which may be obtained under various conditions.

These diagrams are intended to show the general effect on compressive strength of the variation of one factor in the process of manufacture as taken from the results included in this Paper. The ranges shown should not be considered as the maximum obtainable in practice

With all other factors constant the results included in this paper show that differences in manipulation of the mixture by the workmen of several experienced concrete contractors may cause a maximum average variation in the compressive strength of the resulting concrete of 70 per cent. or more.

(C) Relation of Consistency of Mixture to Compressive Strength.—The quantity of water added to the mixture in preparing concrete affects materially the compressive strength at all ages. With the proper quantity of water the strength may be several hundred per cent. greater than that obtained with a large excess of water.

The most satisfactory consistency from the standpoint of strength and durability is a quaking or mushy mixture, and the error should be on the side of using too little rather than too much water, providing it is properly spaded or worked into place in the forms. This statement does not apply to the very dry mixtures used in the manufacture of concrete blocks, etc. In the case of these products the mixture should contain the maximum quantity of water which will permit of the immediate removal of the moulds. This latter mixture has less water than the quaking consistency described above.

(D) Relation of Density to Compressive Strength.—With the same aggregates and the same proportion of cement to total volume of aggregate the mixture having the greatest density will have a high and usually the highest compressive strength.

Density is no criterion of compressive strength of two mixtures of an aggregate if the ratio of cement to total volume of aggregate is not the same.

Density is no criterion of compressive strength of two mixtures of the same proportions of cement to total aggregate if different aggregates are used, although when the aggregates are quite similar they may be comparable.

(E) Effect of Various Exposures on Compressive Strength.—The character of the exposure of the concrete after moulding materially affects its compressive strength. If the original water is permitted to evaporate from the concrete and all water is subsequently excluded, the compressive strength may be reduced 40 per cent. or more. Concrete should preferably be kept wet for several days or weeks after it is deposited if the maximum strength is to be attained.

(F) Effect of Exposure to Steam on Compressive Strength.—Steam greatly accelerates the hardening process and will increase the strength of concrete only a few days old by several hundred per cent., depending on the temperature and duration of exposure.

(G) Relation of Gradation of Aggregate to Compressive Strength.—There is no definite relation between the gradation of the aggregate and the compressive strength which is applicable to any considerable number of different aggregates.

The gradation curve for maximum compressive strength, which is usually the same as for maximum density, differs for each aggregate.

The so-called maximum density curve, which is a combination of the straight line and ellipse, does not represent the curve for maximum density excepting for the particular materials used in the tests from which it was derived, or very similar materials.

No equation for a gradation curve, which can be applied to a number of different aggregates, can be prepared from the results included in this paper.

Maximum density and maximum strength are usually obtained with a concrete in which the ratio of fine to coarse aggregate is not less than one to three. This mixture is usually quite stiff and therefore more difficult to handle than a mixture containing a larger percentage of fine aggregate.

Excessive fineness does not necessarily result in a totally unsatisfactory sand for concrete. A seashore sand having 99 per cent. passing a 50-mesh sieve, when mixed with a good coarse aggregate and cement, was found to give a satisfactory concrete.

(H) Relation of Proportions to the Compressive Strength.—With the relative volume of fine and coarse aggregates fixed the compressive strength of a concrete increases directly as the cement content, but not in a proportionate ratio. An increase in the ratio of cement to total fine and coarse aggregates when the relative proportions of the latter are not fixed does not necessarily result in an increase in strength. For example, a concrete mixed in the proportion of one part cement to nine or ten parts of total fine and coarse aggregates combined so as to give a maximum density may have greater strength than a concrete mixed in the proportion of one part cement to six parts total of the same fine and coarse aggregates, which are not combined to give a maximum density.

CONCLUSIONS.

1. No standard of compressive strength can be assumed or guaranteed for concrete of any particular proportions made with any aggregate unless all the factors entering into its fabrication are controlled.

2. A concrete having a desired compressive strength is not necessarily guaranteed by a specification requiring only the use of certain types of materials in stated proportions. Only a fractional part of the desired strength may be obtained unless other factors are controlled.

3. The compressive strength of a concrete is just as much dependent upon other factors, such as careful workmanship and the use of the proper quantity of water in mixing the concrete, as it is upon the use of the proper quantity of cement.

4. The compressive strength of concrete may be reduced by the use of an excess of water in mixing to a fractional part of that which it should attain with the same materials. Too much emphasis cannot be placed upon the injurious effect of the use of excessive quantities of water in mixing concrete.

5. The compressive strength of concrete may be greatly reduced if, after fabrication, it is exposed to the sun and wind or in any relatively dry atmosphere in which it loses its moisture rapidly, even though suitable materials were used and proper methods of fabrication employed.

6. The relative compressive strength of concretes to be obtained from any given materials can be determined only by an actual test of those materials combined in a concrete.

7. Contrary to general practice and opinion the relative value of several fine aggregates to be used in concrete cannot be determined by testing them in mortar mixtures. They must be tested in the combined state with the coarse aggregate.

8. Contrary to general practice and opinion the relative value of several coarse aggregates to be used in concrete cannot be determined by testing them with a given sand in one arbitrarily selected proportion. They should be tested in such combination with the fine aggregate as will give maximum density, assuming the same ratio of cement to total combined aggregate in all cases.

9. No type of aggregate such as granite, gravel, or limestone can be said to be generally superior to all other types. There are good and poor aggregates of each type.

10. By proper attention to methods of fabrication and curing, aggregates which appear inferior and may be available at the site of the work may give as high compressive strength in concrete as the best selected materials brought from a distance, when the latter are carelessly or improperly used.

11. Density is a good measure of the relative compressive strength of several different mixtures of the same aggregates with the same proportion of cement to total aggregate. The mixture having the highest density need not necessarily have the maximum strength, but it will have a relatively high strength.

12. Two concretes having the same density but composed of different aggregates may have widely different compressive strength.

13. There is no definite relation between the gradation of the aggregates and the compressive strength of the concrete which is applicable to any considerable number of different aggregates.

14. The gradation curve for maximum compressive strength, which is usually the same as for the maximum density, differs for each aggregate.

15. With the relative volumes of fine and coarse aggregate fixed, the compressive strength of a concrete increases directly, but not in a proportionate ratio as the cement content. An increase in the ratio of cement to tótal fine and coarse aggregates when the relative proportions of the latter are not fixed does not necessarily result in an increase in strength, but may give even a lower strength.

16. The compressive strength of concrete composed of given materials, combined in definite proportions and fabricated and exposed under given conditions can be determined only by testing the concrete actually prepared and treated in the prescribed manner.

17. The results included in this paper would indicate that the compressive strength of most concretes, as commercially made, can be increased 25 to 100 per cent. or more by employing rigid inspection which will insure proper methods of fabrication of the materials.

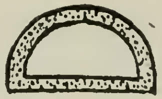
NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

CONCRETE WORKS AT THE HYDRO-ELECTRIC PLANT, KAPONGA, NEW ZEALAND.

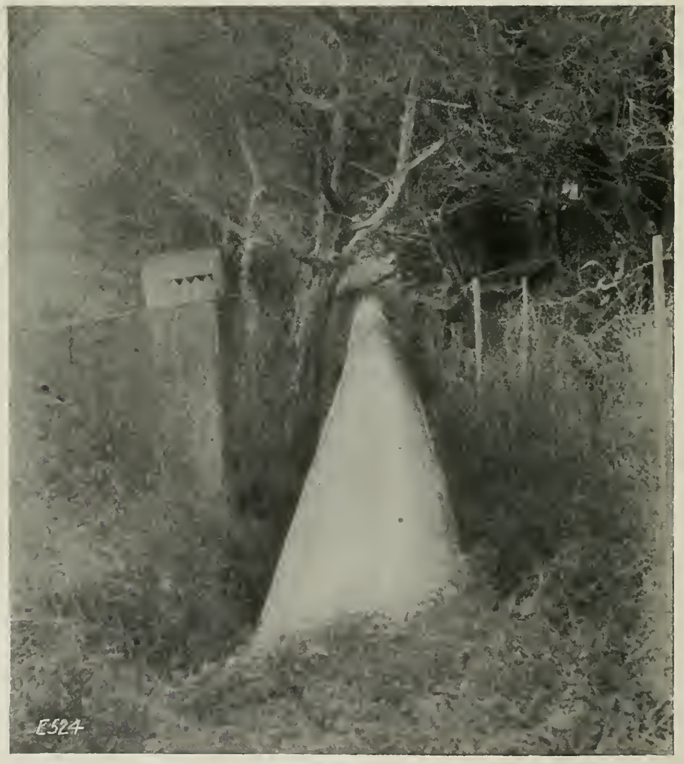
The following particulars and illustrations of some reinforced concrete work carried out in New Zealand, in connection with a large hydro-electric plant, may be of interest:—



The Kaupokonui River runs through the centre of the town of Kaponga, and abounds with good clean shingle, and it was for this reason that so much concrete was used, as the shingle is of easy access and was practically on the job.

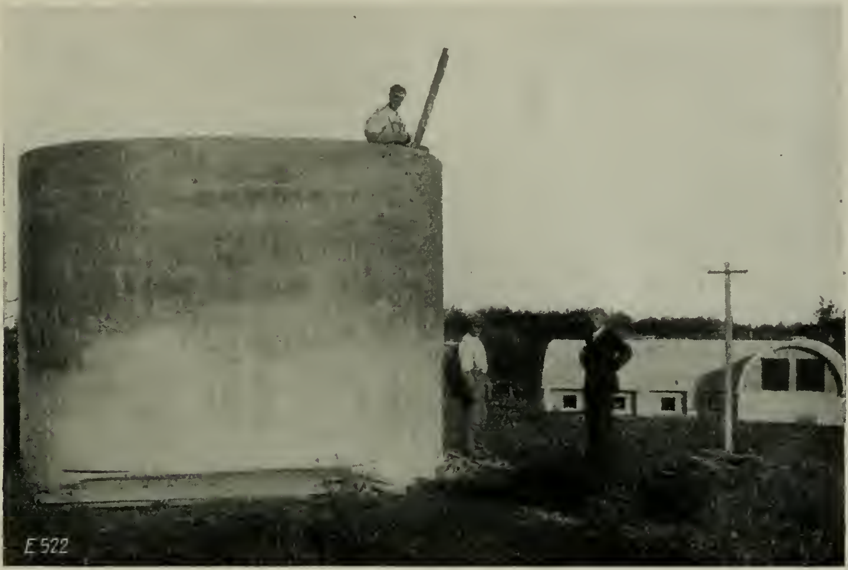
The dam, pipeline, surge tank, power-house, tail race, intake, and poles are all of reinforced concrete.

The dam is 84 ft. long, 8 ft. high, and 9 ft. wide at the base. The spillway is 40 ft. long; the ends are raised 3 ft. above the spillway, and battered up to the high banks at the side of the river; the sluice gate is 3 ft. square, and fitted with an iron door operated by a screw-gear. The foundation is down on the solid rock boulders. The dam is reinforced throughout with $1\frac{1}{4}$ in. indented steel bar and No. 8 chain netting.

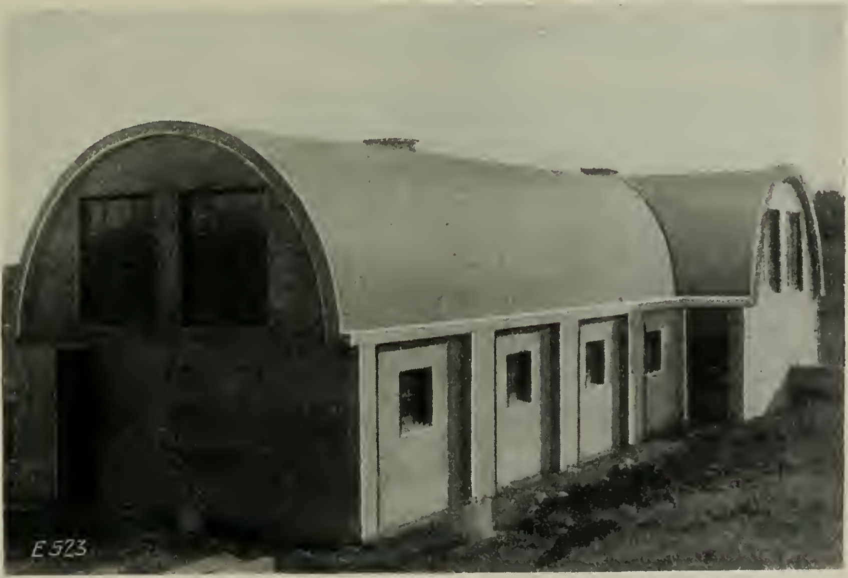


Concrete Pipe Line.
Concrete Work, Hydro-Electric Plant, Kaponga, New Zealand.

There has been a flood over this dam 8 ft. above the spillway, and it stood the strain well, no damage being done, except a few of the boulders were shifted on the down-stream side.



Surge Tank and Power House.



Power House.

Concrete Work, Hydro-Electric Plant, Kaponga, New Zealand.

The pipeline is 13 chains long, 2 ft. 9 in. in diameter; the walls are 6 in. thick, and reinforced 2-in. mesh No. 14 wire netting. It is of the shape shown and one continuous piece of work. There is a static pressure of 9·548 lb. per sq. in. on this pipe, and it is quite tight.

Concrete Poles.

The surge tank is 26 ft. high by 12 ft. internal diameter, 16 ft. being above ground line and 10 ft. below. The walls are 12 in. thick and reinforced with 4-in. triangular mesh.

The intake, pipeline, and surge tank are all in one continuous piece and are watertight.

The power-house is 54 ft. long by 20 ft. wide; the height to the centre of the arched roof is 16 ft. The walls are 6 in. thick, with 12-in. buttresses at 4-ft. centres. The arched roof is 6 in. thick, carried over in one span without any stays or braces. The whole is reinforced with 4-in. triangular mesh. This roof is very strong; all the heavy machinery for the power-plant was lifted off the centre of this roof without any strutting.

The tail race is 5 chains long, 3 ft. 6 in. wide, and 2 ft. 9 in. high. It is the same shape as the pipeline, but the concrete is only 3 in. thick, and there is no reinforcing; it is built in one piece.

The poles are from 25 ft. to 30 ft. long. The 25-ft. poles are 8 in. at the butt and 5 in. at the top; they are square and are reinforced with four rods of ½-in. steel, bound together every 12 in. with No. 8 wire. The 30-ft. poles are similar to the 25 ft., except they are 10 in. at the butt and 7 in. at the top. The poles are made with a 1:3:2 mixture; all the other work is 1:2:4 mixture.

These poles are very flexible; the spring in the end pole in the photograph calls for attention.

This plant was all to the design of Mr. Horace Priestley, A.Am.I.E.E., Engineer to Kaponga Town Board, N.Z. Mr. E. Cave was the contractor, and the contract price was £1,649.

Dam and Intake.

Concrete Work at the Hydro-Electric Plant, Kaponga, New Zealand.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

American Civil Engineer's Pocket Book.—Third Edition. Editor-in-Chief, Mansfield Merriman, M.Am.Soc.C.E.

Publishers: John Wiley & Sons, New York, and Chapman & Hall, London. Price 21/-

This pocket book is of a handy size (7 in. by 4½ in. by 2¼ in.), and, although printed in small type, the letterpress is clear and distinct; and the eye-weariness so frequently experienced when reading a book of this type is entirely absent. The irritating effect due to the printing showing through from the reverse side and succeeding pages has been avoided by the use of a thin but opaque paper. The letterpress, tables, illustrations, and diagrams are clear and conveniently arranged, and considerable credit is due to the editors and publishers for the evident care that has been taken in the compilation, arrangement, and general production.

Sufficient indication as to the amount of information given may be deduced from the number of pages of subject-matter (1,502); while the names of the several editors are ample guarantee of the value of the articles of which the sixteen sections are composed.

The treatment of the several subjects has been condensed as much as possible, consistent with a sufficiency of detail to ensure a proper understanding of the principles involved and the limitations of the various methods of treatment, formulæ, etc.; and although the subject-matter is necessarily treated from an American standpoint, there are only a few instances where it is not equally consistent with English practice.

In a review of a book of this nature, time and space do not permit of a detailed survey of all the innumerable subjects dealt with; but a necessarily cursory examination of each section leaves the general impression of an exceptionally useful reference book.

The subjects and editors of the sixteen sections are as follows:—

Section 1.—Mathematical Tables: Mansfield Merriman.

Section 2.—Surveying, Geodesy, and Railroad Location: Charles B. Breed.

Section 3.—Steam and Electric Railroads; Walter Loring Webb.

Section 4.—Materials of Construction: Rudolph P. Miller.

Section 5.—Plain and Reinforced Concrete: Frederick E. Turneaure.

Section 6.—Masonry, Foundations, and Earthwork: Ira O. Baker.

Section 7.—Masonry and Timber Structures: Walter J. Douglas.

Section 8.—Steel Structures: Frank P. McKibben.

Section 9.—Hydraulics, Pumping, and Water Power: Gardener S. Williams.

Section 10.—Water Supply, Sewerage, and Irrigation: Allen Harjen.

Section 11.—Dams, Aqueducts, Canals, Shafts, and Tunnels: Alfred Noble and Silas H. Woodard.

Section 12.—Mathematics and Mechanics: Edward R. Maurer.

Section 13.—Physics, Meteorology, and Weights and Measures: Louis A. Fischer.

Section 14.—Steam and Electric Engineering: George A. Goodenough and F. Malcolm Farmer.

Section 15.—Highway Engineering: Arthur H. Blanchard.

Section 16.—Harbour and River Works: Frederic R. Harris.

Section 14 deals only with the outlines of fundamental principles and facts, and is not meant to be for the use of mechanical or electrical engineers, but for civil engineers whose knowledge of the subjects is limited.

A list of sub-sections and articles with page numbers is placed at the commencement of each section, and a most thorough and complete subject index is inserted at the end of the volume.

It must be presumed that the publication of this exhaustive pocket book indicates a demand for a book of this type, as, if such a demand did not exist, the infinite labour required in its preparation would hardly have been undertaken; otherwise it might have been thought that all reasonable requirements would have been met by "Trautwine," which, in the past, has been looked upon as the standard American engineering pocket book.

The Stability of Arches. By Ernest H Sprague, A.M.I.C.E.

London: Scott, Greenwood & Son. Vol. xx. of the Broadway Series of Engineering Handbooks. 141 pp. Price 4/- net.

Although we have had in recent years a number of books upon the theory of arches by American writers, very few books by British authors have appeared.

Mr. Sprague, who acknowledges the work of German writers, with which he obviously has an excellent acquaintance, has given us in the present book a very readable and, at the same time, very useful *résumé* of the subject. His writing is in the succinct style which the American and German authors favour, but which British students usually find rather too condensed for their taste. Doubtless he has been hampered by considerations of space, and perhaps also by fear of falling into the opposite error of verbosity; but in our opinion the fuller treatment, in which the various points are explained at considerable length, is to be preferred, especially for those readers who have not a lecturer to refer to for further explanation. In America most of the text-books are used as class-books to summarise the work done in the class where the detailed explanation is given, and that accounts for their condensed style.

After an interesting historical introduction, Mr. Sprague first deals with the statically determinate, or three-pinned arch; in Chapter III. the elastic theory of the arch is considered, the special cases of the two-hinged and hingeless arches occupying the attention of the next two chapters. In each case a numerical example, with the tabulations for the summations involved, is given; the author points out that the two-hinged arch has not many points in its favour, except comparative ease of calculation, as against the hingeless arch. As the latter is very common in practice, we suggest that in future editions the author makes this chapter more extensive.

The next two chapters deal with masonry and concrete arches, and will be found interesting as well as useful. In the final chapter the determination of the stresses in masonry and concrete arches from a known line of pressure is treated. The usual cubic equation for neutral axis of reinforced concrete sections is derived and shown to be cumbersome in use, Professor Melan's approximation being recommended. A trial and error method for the given numerical conditions can often be expeditiously employed for this case, and would form a useful addition to the book.

The book can be strongly recommended to students and engineers in practice; it will not satisfy the demands of those engineers who clamour for "simple" formulæ. The wisest course for those whose mental equipment does not comprise a sufficient knowledge of the laws of mechanics to enable them to make the calculations involved in the elastic theory of arches is to leave such calculations to someone else.

Earth Pressure, Retaining Walls and Bins. By Professor Wm. Cain, M.Am.Soc.C.E.

London: Chapman & Hall, Ltd. 287 pp. Price 10/6 net.

The scientific design of structures subjected to pressure from earth and granular material presents considerable difficulty, on account of the paucity of exact knowledge as to what pressures these materials can exert upon the walls supporting them. In the case of dams, and other structures subjected to water pressure, there is some difference of opinion as to the stresses in the material, although the pressures are accurately known; but in the case of retaining walls for earth and bins we have the additional possibility of error in the computation of the pressure which the structure may be called upon to resist.

Professor Cain has already contributed to the subject in the journals of the American professional societies, and the collection of his investigations in book form will be a useful addition to the engineer's library.

The first chapter deals with the laws of friction and cohesion, and is based upon Coulomb's theory, viewed in the light of recent experimental knowledge as to the constants for the different materials.

Chapters II. and III. deal respectively with graphical and analytical methods of investigating the pressure due to non-cohesive earth, particular attention being given to Mohr's circular stress diagram; the fourth chapter explains the design of retaining walls, and contains useful tables and other data, particularly with reference to counterforted walls.

The pressures due to coherent earth are treated in the next chapter; consideration is given to the resisting power of foundations, screw piles, and braced trenches, and also to the pressure of tunnel linings.

In the sixth chapter the pressures upon deep and shallow bins are treated.

An analysis is given in an appendix of the stresses in "wedge-shaped" beams, such as occur in the design of counterforts and footings.

The general treatment in the book is of the concise, condensed type which is typical of the American text-books; it is a book which requires close study by those readers who do not already possess some knowledge of the subject, but it is only by such close study that we can expect to become fully acquainted with a difficult subject.

Masonry Dam Design. By C. E. Morrison, C.E., Ph.D. and O. L. Brodie, C.E.

London: Chapman & Hall, Ltd. New York: J. Wiley & Sons. 276 pp. 2nd edition. Price 10/6.

In this edition of their book upon masonry dam design the authors have added chapters upon overfall and arched types of masonry dams, and have given a useful selection in chronological order of cross-sections of masonry dams.

The book as a whole gives a very good general survey of the problems involved in dam design, and deserves to be studied carefully by all engineers interested in the design of such structures. Considerable attention is given to the effect of uplift pressure and ice thrust—questions which have often been disregarded by designers, but which are of great importance in practice. A series of six formulæ are derived for design to meet the various conditions of loading and methods of failure.

A chapter which should prove of considerable interest and value to designers is that upon "Recent Considerations of the Condition of Stress in a Masonry Dam." This chapter gives a *résumé* of the paper by Mr. L. W. Atcherley and Professor Karl Pearson which provoked an animated controversy a few years ago, and outlines the other papers and experiments which were published in this country as a result of the deductions from Atcherley and Pearson's theory.

The chapter on the arch dam includes a very full mathematical treatment of the formulæ involved, based upon a method outlined by Mr. R. Shirreffs in the discussion of a paper by Messrs. Harrison and Woodard, read before the American Society of Civil Engineers.

The printing and illustrations of the book are up to the high standard which is characteristic of Messrs. Wiley's publications.

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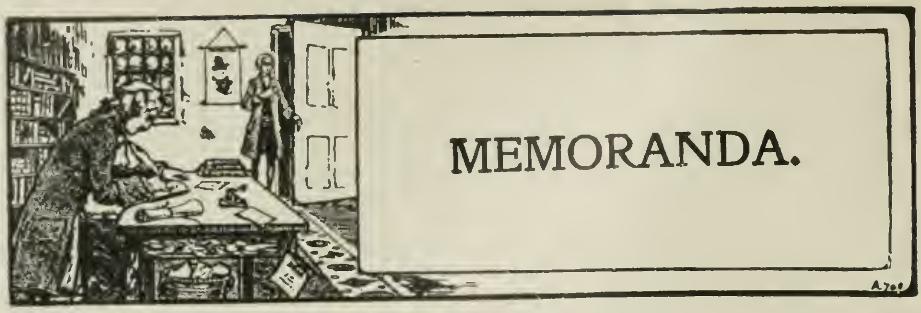


MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

The Concrete Institute.—The 1916-17 session of the Concrete Institute commences on November 23rd, when the presidential address will be delivered by Mr. F. E. Wentworth-Sheilds, M.Inst.C.E., etc. The meeting will be held at Denison House, 296, Vauxhall Bridge Road, Westminster, S.W., at 5.30 p.m.

The next two ordinary general meetings will be held as follows:—

December 21st, at 5.30 p.m., when Professor Henry Adams, M.Inst.C.E., etc., past president of the Institute, will read a paper on "Pile Driving and the Supporting Power of Piles"; and

January 25th, 1917, when Mr. C. R. Peers, Chief Inspector of Ancient Monuments, H.M. Office of Works, will read a paper on "The Care of Ancient Monuments."

Housing and Town Planning.—Forthcoming Scottish National Congress.—The Scottish National Congress to consider the preparation of housing and town planning schemes to be put in operation at the close of the war will meet at the Trades Hall, Glasgow, on Monday and Tuesday, November 27th and 28th. The Congress will be attended by representatives of local authorities, professional and other associations, and national associations of employers and workmen.

Resolutions will be submitted and discussions will take place upon the following subjects:—

1. The preparation of housing schemes by local authorities and other agencies, those schemes being held ready to be placed in operation at the close of the war, and the provision by the Government of the necessary capital to carry out the schemes.

2. In view of the scarcity of housing supply the desirability of giving local authorities greater and more varied power to stimulate and aid constructive housing action.

3. The need for pressing forward with the preparation of town-planning schemes so as to secure right conditions for housing developments in regard to lay-out of sites, provision of amenities, and planning of arterial and other roads.

4. The desirability in the interests of the health and happiness of the community of building self-contained dwellings with gardens instead of tenements.

Concrete Construction at Canberra, the Commonwealth Capital.— In a specially contributed article in the *Commonwealth Engineer* on the engineering features of the Commonwealth Capital, Canberra, it is stated that: "A feature of the work so far carried out has been the amount of concrete that has been used. One of the many applications has been in the manufacture of fencing posts, which are used for all rabbit-proof fences, partly because they are cheaper than wood, and partly because the country is infested with white ants."

Later on in the article, under the title "Surveys," the writer says: "The territorial boundary has been permanently marked throughout by means of large posts at all angles and at every mile and half mile on straight runs. In addition, concrete blocks or galvanized pipes have been sunk below the surface at frequent intervals, the positions being, of course, indicated by cairns. . . . Four types of concrete blocks are in use for permanent marking of surveys."

We hope later on to deal more fully with this concrete work.

Concrete Cottage Building.—At Dunfermline permission has been granted to Mr. Walter Wilson, Clerk of Works, to erect an experimental cottage in concrete, according to a special project devised by himself.

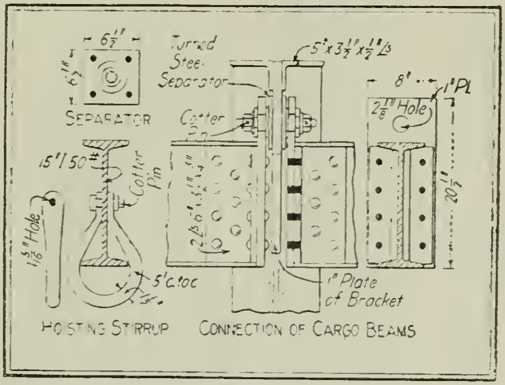
Reinforced Concrete Cottages.—Arrangements are being made for the erection of some hundreds of cottages for the accommodation of the workpeople employed in the Derry shipbuilding yards. Most of the cottages, it is expected, will be of reinforced concrete. The plans will come before the Derry No. 1 Rural District Council. The Derry Industrial Dwellings Company, of Foyle River Buildings, Pier Head, Liverpool, are responsible for the project.

Hong Kong Breakwater.—The Governor of Hong Kong, in his annual report to the Colonial Office, reports the completion of the Hongkoktsui breakwater and contingent works. The breakwater is 3,325 ft. in length. It is faced with concrete blocks, and in all 12,453 blocks were used, of which 11,579 were pitching and paving blocks of two tons each.

Foundations of Edinburgh's New Generating Station.—The members of the Lighting Committee recently, at the invitation of the Chairman, visited the site of the new works at Portobello. The site is eight acres in extent, but at present the foundations for two units only have been laid. The foundations are of reinforced concrete. The parts where the pillars and beams of the buildings are to rest are solid concrete foundations of 20 ft.

Swinging Cargo Hoist Beams for New Pier Shed.—By designing the end connections with pin details to allow the beams to swing into a position resulting in applied loads parallel to the webs only, it was found possible to use I-beams instead of built-up plate girders for the cargo hoist girders in the new West Fifty-seventh Street municipal pier to be built in New York City. This pier shed has the standard 20-ft. panels used in New York dock construction, is of the two-storey type, with high 70-ft. cargo columns at each bay.

The accompanying drawing indicates the detail used in making the swinging connection to the bracket carried by the top of the column. A 2-in. pin placed above the ends of the beams passes through the 1-in. plate of the column bracket and through 1-in. plates riveted to the ends of the beams. The hoisting stirrups placed on 5-ft. centres are also a new design, looping around the lower flange of the I-beams as shown. This design has been worked out under the supervision of Charles W. Staniford, Chief Engineer of the Department of Docks and Ferries, New York City, of which R. A. C. Smith is Commissioner and R. C. Harrison is Deputy Commissioner.—*Engineering Record.*



Radiographs of Reinforced Concrete.—A promising examination of reinforced concrete by the aid of Röntgen rays is mentioned by Mr. E. Stettler, of the Swiss Railway Department, in the *Schweizerische Bauzeitung.* A plate, 18 by 24 cm., 7·5 cm. (3 in.) thick, was built up of ordinary concrete and commercial iron rods, 7 mm. in thickness; the plate was examined in the Röntgen Institute of Berne. The first radiograph obtained, which is reproduced in the journal mentioned, does not show more than the dark shadings of the crossing rods on a less dark background, and the somewhat imperfect hook joint formed by two of the rods. But cracks in the concrete and indications of rusting, if present, would probably also be perceptible. The examination is quite easy and cannot do any harm to the building, and the dis-

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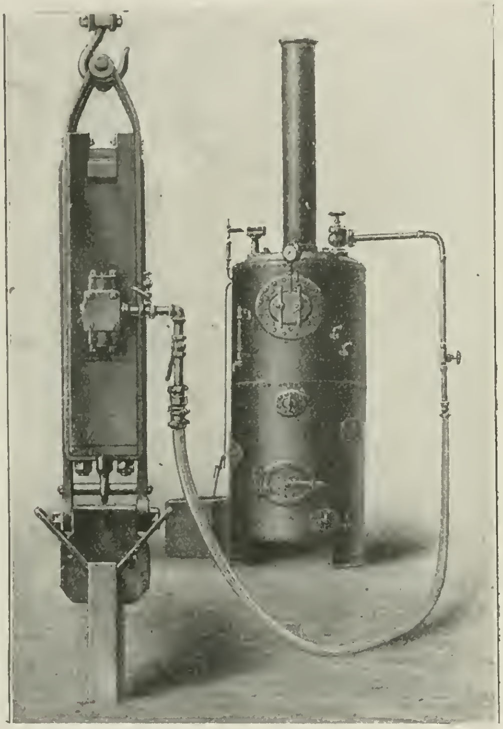

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tribution of the rods in the finished product could at any rate be studied if the process were applicable on a large scale.—*Engineering.*

Nigerian Railways.—The design of the quay wall at Port Harcourt consists of concrete in mass work throughout, the foundation wall being cast in trench between steel sheet piling, and the upper wall in open trench between wood shuttering, with suitable forms for landing steps, subway, etc. Landing and embarking facilities are to be provided for small craft by flights of steps every 450 ft. The proposed full length of quay wall is 1,805 ft., of which 500 ft. are to be constructed as soon as possible. Dredging will be necessary to remove the bluff in front. Derrick cranes have been purchased from the Clyde Navigation Trust for use in the construction of the wall. The concrete mixer, supplied by Messrs. Stothert and Pitt, is of 21 ft. capacity, unmixed batch, arranged for fixing on railway wagon, with side loader and extended frames for loading the ship at ground level, driven by a steam engine complete with mixer on skid. Peter's patent one cu. yd. grab (6 to 1 purchase) is provided for excavation in trench. This grab can be opened at the bottom, should it grip any obstacle or in relieving undue suction, by merely re-lifting after paying out a few feet of slack chain. The pumping plant for use in the trench in open cutting consists of a Tangye 6 in. by 6 in. by 12 in. horizontal special pump, capable of discharging 7,300 gallons per hour. The stone breaker and screening plant, of capacity of ten tons per hour, for use in Ishiago Quarry, are to be supplied by Messrs. H. R. Marsden, Ltd., of Leeds. The Universal Joint Steel Piling, 15 in. by 4¾ in., for sheeting in the trench, is supplied by the British Steel Piling Co., Ltd., and a considerable quantity has been sent out; but the shipping difficulties are great, especially as regards cement.—*Colonial Journal.*

Concrete Arched Dam, Sorell, Tasmania.—In the *Commonwealth Engineer* Mr. W. Nimmo, Assoc.M.Inst.C.E., of the Public Works Department of Hobart, gives the following particulars :—

A concrete arched dam has recently been constructed for the purpose of supplying water to the town of Sorell, South-eastern Tasmania. The dam is situated on the Sorell rivulet at a point where the stream passes between two hills composed of bluestone. The construction of an earthen dam would have involved an expensive bywash, and a concrete dam was therefore decided on. The dam has a length on the crest of 155 ft., and a radius at the upstream face, which is vertical, of 110 ft. The greatest depth of water is 23 ft., and the storage capacity is 18 million gallons. For a length of 80 ft., at the centre of the dam, the crest is raised 3 ft. above full supply level, the discharge of flood waters being confined to the ends of the dam, where the maximum fall is only 10 ft., rendering a water cushion unnecessary.

The profile is designed on the usual assumption that the dam acts as a portion of a rigid cylinder subjected to an external pressure. The thickness is 2 ft. for a depth of 10 ft. below the raised crest; the downstream face then batters 1 in 5, giving a thickness of 6 ft. at a depth of 30 ft. The stress allowed on the concrete was 15 tons per sq. ft. Considering the nature of the abutments a higher stress might have been adopted, but, as assistants with previous experience of this type of construction were not available locally, it was deemed advisable to adopt a moderate stress. As an additional precaution, the original design provided for horizontal and vertical reinforcement with second-hand 20-lb. rails on both upstream and downstream faces, but, as these were unobtainable, 1-in. round rods were substituted. A floating arm is employed for the outlet pipes, and both outlet and scour valves are placed in a concrete casing.

The dam contains about 450 cu. yds. of concrete. The cost, including clearing and outlet works, was £1,300. The dam was designed by Mr. Nimmo, and constructed under his general supervision by Mr. R. Gould, Engineer to the Sorell Council.

TRADE NOTE.

Messrs. Jas. Lumsden and Co.—The Calcutta Corporation, we learn, has placed an order with Messrs. Jas. Lumsden and Co., the concrete engineers, of 15, Clive Row, Calcutta, for over 1,200 pieces concrete fencing posts to be erected along the east side of Circular Road.

PROPOSED WORKS.

Brighouse.—Plans have been passed for a reinforced concrete coal store for the Gas Committee of the Corporation.

Essex.—Subject to the necessary consent being obtained from the Government, the Essex County Council has accepted the tender of Messrs. W. and C. French, amounting to £713 12s. 6d., for the construction of reinforced concrete piling and wall at Roydon Bridge.

Halifax.—The Halifax Corporation propose accepting the tender of the Midland Counties Reinforced Concrete Company of £685 for the reconstruction of Clark Bridge.

France.—H.M. Consul-General at Havre states that about £8,000,000 is to be spent on port improvements at Havre, half the cost of which will be borne by the State and half by the local Chamber of Commerce. The projected works include the construction of two new basins.

Dundee.—The Dundee Harbour Board has decided to promote a Provisional Order Bill to secure additional borrowing powers for urgent work, including the reconstruction of the West Camperdown Wharf and the completion of the eastern jetty in a more permanent form. The estimated cost is £180,000.

Gosport.—The Gosport and Alverstoke Urban District Council is to consider a scheme for alterations at Gosport Hard, which will involve the construction of a wall in reinforced concrete.

Glasgow.—It is recommended by the Electricity Committee of the Corporation that Messrs. Train and Taylor, the contractors for the concrete work at the new generating station at Dalmarnock, should be authorised to proceed with the construction of the outfall concrete culvert at a cost of £8,500.

California.—The Great Western Power Company, of Oroville, California, has prepared plans for the construction of a second power plant which will involve the expenditure of 25,000,000 dollars. Water will be brought from Lake Almanor in a great concrete aqueduct.

Vancouver.—The Canadian Trade Commissioner reports that the Canadian Pacific Railway Company has plans for wharves at Vancouver to cost £308,300, and that the city authorities are about to spend £1,027,700 on wharf extensions.

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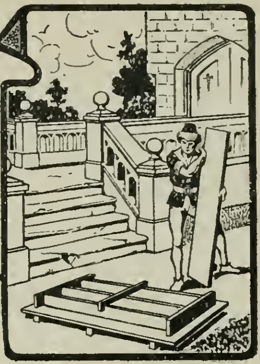
CONCRETE THE MONEY SAVER



CONCRETE BLOCKS AND HOW TO MAKE THEM.

(*Continued.*)

In the following articles (which have been specially contributed), it is intended to give instructions of how to make the concrete blocks. The machinery, moulds, etc., are referred to only in a general way, as we have already illustrated and described from time to time the principal types of block-making machines, etc., that are on the market in this country.—ED.

MAKING A MOULD FOR CONCRETE BLOCKS (*cont.*).

LINER 12 shows the liner which is attached to the right-hand side door when corner blocks are required, and liner 13 shows the construction of the liner for the front door, which is also necessary for corner blocks. The position of the liners are indicated in *Figs.* 4 and 5 (October issue,) and from these it will be found very simple to fit up the mould.

Fig. 9 shows the pallet (upon which the blocks are made) in detail. The plain side of this is the face, the battens resting upon the bottom of the mould. It must be clearly understood that if 100 blocks per day are to be made it is necessary to have 200 of these pallets, as each block must be made on a pallet, and they require to be left upon the pallet for at least two days. It will, therefore, be readily understood that it is necessary to have sufficient pallets for at least two days' work. Upon the third day the blocks can, with care, be taken from the pallets and these can then be used over again. It will be found advisable to have the corner blocks on the pallets for at least three days. The blocks should be watered each day after making so as to allow the cement to get its proper action. *Figs.* 10 and 11 show the arrangements for the iron fastener, which will hold the mould together tightly, while the blocks are being tamped. It is a very simple arrangement, but it is very effective and very quickly operated. *Fig.* 10 is simply a piece of 1½ in. by ½ in. iron bent to shape, while *Fig.* 11 is a bracket which is screwed to the back of the mould, and about 2½ in. to 3 in. from the top edge of the mould. Two of these brackets are required to the set. In each of the brackets are ¼ in. holes, which are matched with holes in *Fig.* 10. Through these holes ¼ in. bolts are fixed with just sufficient clearance so as to allow *Fig.* 9 to move freely. The bolts form a pivot upon which the fastener (*Fig.* 10) works.

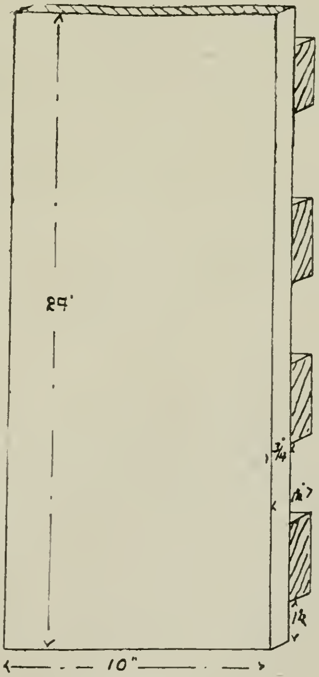


FIG. 9. PALLET

The mould should be made in yellow pine or American white wood, but, of course, other wood such as a good class red deal would do, but it will not stand so well. The top edges should be lined up with strips of iron about ½ in. thick which will protect the top edges from chipping and wearing. The outside of the mould should be painted, while the faces of the liners, etc., should be given three or four coats of French polish, put on with a brush, or two or three coats of shellac dissolved in methylated spirits. This will keep out the wet. *Fig.* 12 is an alternative type of pallet which is more convenient to handle for the ordinary walling blocks (18 in. by 9 in. by 4⅛in.).

HOW TO MAKE CONCRETE BLOCKS.

This is fairly simple, and it is work which can be left to any average labourer after he has been shown how to make two or three blocks, but, as mentioned, in "mixing," unless the material is properly mixed it is impossible to make good and satisfactory blocks.

Pressure Machines.—If a mechanical press is used all that is necessary is to place a pallet on the bottom of the mould box and to fill it up with the material which is struck off level with the top, and then to move the box under the die. The die is then lowered by various means and the pressure is applied. After this is completed the die is raised back to its "rest" position and the mould box moved to the place where it was filled. It is then unfastened and the block taken out and laid on one side to harden off for 24 hours, and the operation again repeated. It must be noted that for each block that is made a pallet or carrying-off plate is required. In some of the power presses it is possible to make 1,000 to 1,600 blocks per day.

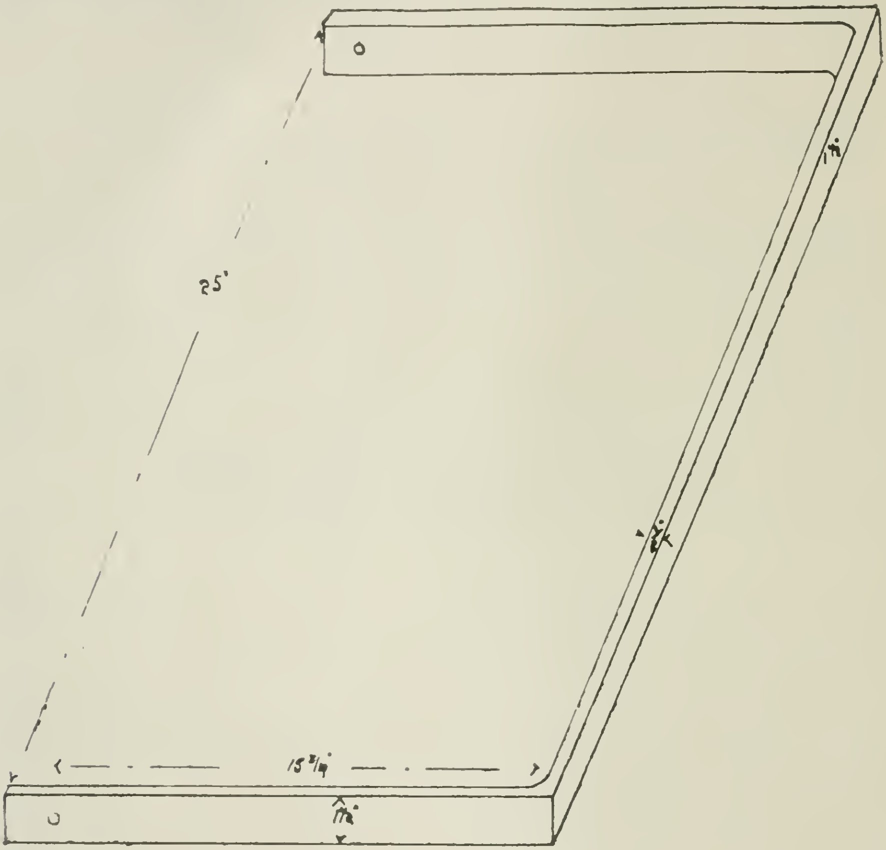


Fig. 10.

Pressure machines are quite suitable for partition slabs, cavity wall blocks, but for hollow bocks they are not quite so efficient. With hollow blocks, the cores which form the hollows must stand upright in the mould so as to allow the pressure, when applied, to disperse with equality throughout the block. This necessitates the face of the blocks (*i.e.*, the side of the blocks which are exposed to the weather) being on the side, and it has been found from experience that when blocks are made with their faces on the side, that they are not so weather resisting as if made on a face up pressure machine.

When hydraulic pressure is used a more condensed block is obtained, but the rapidity with which they are made is greatly reduced.

Hand Tamping.—Now we will deal with hand tamping. This is a simple process, but unless carried out in a perfect manner it will be found that the blocks are slightly porous, but if the following instructions are carefully followed satisfactory blocks can be obtained. Having selected the machine you intend to use, it will be found that for outside work it is necessary to *face* the blocks. This means that a block which is composed of a mixture of six aggregate to one of cement has a facing of fine material which is mixed with two and a half of washed sand to one cement. This face is only about ½ in. thick, and makes the blocks more impervious to the weather than if it were the six and one mixture throughout. If a face down machine has been purchased it is a simple method to make the blocks. First, the pallet is placed in the mould and then the facing material is filled in. This should only be about ½ in. in thickness. Upon this the six and one mixture is filled and the whole is tamped or rammed down together. Before the next layer is filled into the mould the face should be "scratched" with the scratcher, as illustrated in *Fig.* 21 (see next issue). This insures perfect adhesion of the second layer to the first. The second layer can then be filled in, and the tamping operation repeated, and this face should also be scratched, and so on, until the block is completed.

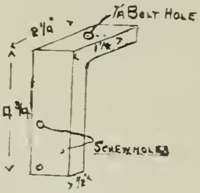


FIG 11.

If a "side face" machine is used it is not quite so easy to have the fine facing of even thickness, but with a little care this can easily be got over, but nearly all the hand tamping machines which are upon the English market are "face down" machines.

When coke breeze is used for making blocks it will be necessary to have a fine facing of washed sand, mixed two and a half of washed sand to one cement. The backing material could be composed of three of coke breeze, three of sand, and one cement. This will ensure a fairly water-proof block. The same applies where pumice or any other porous material is used for building blocks.

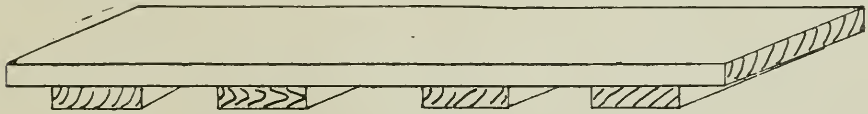


FIG. 12.

Curing.—This is an all-important item in the manufacture of concrete blocks, and unless they are properly "cured" it will be found that they will have the tendency to crumble. By "curing" is meant the ageing, and thus the crystallization of the cement. To obtain perfectly satisfactory blocks the following instructions must be strictly adhered to. As mentioned before, the mixture for blocks is only wetted to a semi-dry consistency, and it is common knowledge that in order to obtain the hardest concrete a fair amount of water must be used. It will be said, "Then how do the blocks described here harden?" But there is a simple method, and that is the "curing," by which it is possible to harden the blocks just as well as if mixed wet. The method of curing is as follows.

After the blocks have been made twenty-four to forty-eight hours, according to their shape and size, they are removed from their pallets and laid out in the curing yard in rows, and a passage left so as to enable a man to get between every third row. This will allow a man or boy to go between and water either with a can or hose. This watering must be carried out every day for six or eight days. If it is hot weather it may be necessary to water twice a day. This is the "curing" process, and it is well to remember that too much water cannot be applied to the blocks. After this they can be stacked up to dry off until wanted for use, but they should never be used under a month at least. They should be protected from the sun and also from frost.

If it is necessary for blocks to remain on the pallets longer than 24 hours, they must be watered while they are on the pallets, and they should be watered (always) within 24 hours of their being made, and the watering must then be continued as before described.

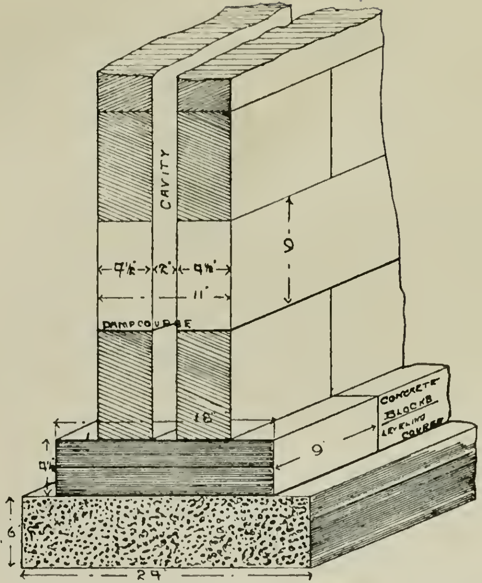
Types of Blocks in Use. — There are many different types of blocks in use for building purposes, and it is always advisable before adopting a special system of blocks to ask the advice of a specialist whether he thinks the system is practical and will pay. As is well known, in different localities there are different bye-laws. In some localities the authorities will not permit the use of hollow concrete blocks, while the bye-laws, as a whole, will not allow a house or building to be constructed with 6 in. concrete walls, although 6 ins. of concrete is as strong and as substantial as 9 ins. of brickwork. But there is no departing from the bye-laws, and so we must make our materials (at present) to suit the existing bye-laws, but when the authorities awaken to the strength and durability of concrete it will come into its own, and then it will be seen by the few instances mentioned that it will pay to make sure that the blocks intended for use are practical and also substantial.

The first concrete blocks which were made were solid, but it was found that these were expensive to make, heavy to handle, and were porous. So another system of blocks was invented, and these were called hollow blocks, see *Figs.* 14, 15, and 22. These are a better kind of block altogether, being cheaper to make and are a great deal lighter to handle, and with a fine facing can be made practically weatherproof. They are more in everyday use than any other type of blocks. There are many different shapes of blocks in use, but in these articles only those are described which are in everyday use, and which are considered practical. But before leaving the subject it must be mentioned that the partition blocks, such as are shown in *Figs.* 16 and 17, and which are made of coke breeze and pumice, are now extensively used in brick buildings (as well as concrete). These are made in various sizes and thicknesses, but the most common size is 24 in. by 12 in. by 2 in., or 2½ in. or 3 in. Some other types of blocks are shown in our illustrations, but as they are not in common use no particulars are given here.

TYPES OF BLOCKS MOST SUITABLE FOR BUILDINGS.

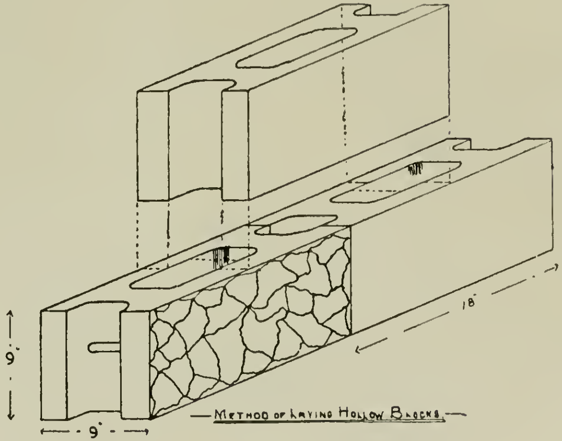
As mentioned in the preceding paragraphs, there are many different types of blocks which are quite suitable for house and cottage building, but the ones which are most in common use in this country are the hollow block and the cavity wall block. On the whole there have been more hollow blocks used than cavity blocks. There are many different sorts, sizes and shapes of hollow concrete blocks, and some of the most popular types are shown in *Figs.* 14, 15 and 22. The sizes of same are shown in the illustrations, and it will be seen that they vary from 18 in. by 9 in. by 9 in. up to 32 in. by 9 in. by 9 in. Some hollow blocks are made on pressure machines, while others are made on hand tamping machines. With the pressure machine the material is simply filled into the mould box and it is struck off level with the top. The box is then placed under the press and the pressure is brought into action by the various mechanical processes. This is all that has to be done to make the block. In the case of a hand-tamped block the operation is different, but this has been fully described under the heading of "Hand Tamping." In some instances the hollow block has become unpopular, but this has only been in a few isolated cases where the houses have proved damp after erection. This can be traced to many reasons, such as poor aggregate (which has not been freed from loam or other impurities), when the facing material has been mixed too weak, improper tamping, such as would be the case when the blocks are made by piece-work and when proper supervision has been lacking, bad curing, etc., etc.

But this is no reason for condemning the hollow block, for good blocks can be



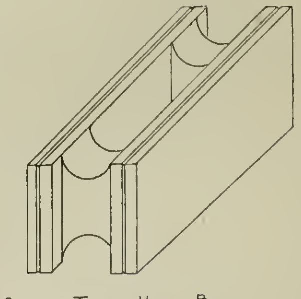
— SECTION OF CAVITY WALL SHOWING FOOTINGS ETC —

Fig. 13.



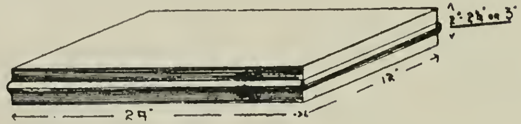
— METHOD OF LAYING HOLLOW BLOCKS —

Fig. 14.



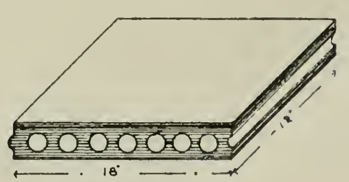
ANOTHER TYPE OF HOLLOW BLOCK

Fig. 15.



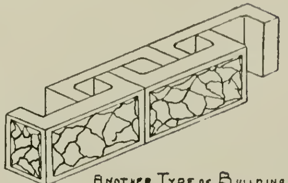
PARTITION SLAB

Fig. 16.



— HOLLOW PARTITION SLAB —

Fig. 17.



ANOTHER TYPE OF BUILDING BLOCK

Fig. 18.

made if proper care and attention is given to the aggregate, mixing, making, and curing. The facing material should always be gauged with two or two and a half of washed sand to one of cement. In some cases a waterproofing compound is mixed in the facing material, but this adds slightly to the cost of the block.

In many instances the hollow blocks when erected are given a coat of rough-cast which is also to ensure their being damp-proof, but when a waterproofing compound is used there is no need for the rough-casting, so the cost of one balances the cost of the other, and if there is any difference at all in the cost it is in favour of the block which has had the waterproofing compound used in the facing. The blocks can be made with the desired face, such as plain face, rock, sparrow picked, or any plain or ornamental pattern which may be desired.

There are many reasons advanced in favour of the use of hollow concrete blocks, such as the saving of material as against bricks or masonry, or even cavity wall concrete blocks.

The cost of laying is also considerably less than for brickwork, even in the case of the larger blocks where two men are needed to lay them, but this can be easily understood, as it will be seen that when laying a block of, say, 18 in. by 9 in. by 9 in. in size the man is laying 12 bricks, while in the case of a 32 in. by 9 in. by 9 in. block 32 bricks are displaced. Then again, the cost of laying material is diminished, as the number of joints are considerably less than the joints in brickwork. They are also good resisters of fire, and a more even temperature is obtained in the house or building, it being cooler in summer and warmer in winter. The holes in the hollow blocks can be utilised for the running of electric wires, pipes, etc. In the first instance a solid block was used, but it was found that this was porous, heavy to handle, and rather expensive to make. The hollow block was then invented, and is a good improvement. It is cheaper to make, lighter to handle, and has the advantages as before mentioned. The other type of block which is now commonly used is the cavity block. A section of a cavity wall is illustrated in *Fig.* 13, which shows the method of laying, etc., but larger or smaller blocks than those shown in the illustration can be used according to requirements. The inner wall is tied to the outer wall by means of wall ties, which may be either painted or galvanised. One wall tie is required to every square yard, and the cost of these is not a large item, the price ranging from 40s. to 70s. per 1,000 according to finish and strength of the tie.

A 16 in. by 9 in. by 4½ in. cavity block weighs 35 lb. approximately.
,, 18 in. by 9 in. by 4½ in. ,, ,, ,, 40 ,, ,,
,, 32 in. by 9 in. by 4½ in. ,, ,, ,, 70 ,, ,,
,, 18 in. by 9 in. by 9 in. hollow ,, ,, 75 to 80 lb. approximately.
,, 32 in. by 9 in. by 9 in. ,, ,, ,, 135 to 140 lb. ,,

The cost of laying 18 in. by 9 in. by 4½ in. cavity blocks is generally about *7s. per 100, which includes the cost of scaffolding, etc., and the writer has had 320 blocks 18 in. by 9 in. by 4½ in. laid by one blocklayer in one day of 10 hours. This is equal to upwards of 2,000 bricks.

It will perhaps be well to mention that most hollow block machines will make cavity blocks, and also partition slabs, which is an essential point with the small builder, who, as a rule, has not the capital to spare to lock up in several kinds of machines.

ERECTION OF BUILDINGS WITH CONCRETE BLOCKS.

The erection of buildings with concrete blocks can be well done by any ordinary bricklayer if only a little time and care is given to the work.

A word here, perhaps, will not be out of place to the architect or designer of concrete block buildings. Firstly, if the blocks to be used in the proposed building are 18 in. by 9 in. by 4½ in. or 9 in. thick, it must be remembered that all outside door openings and window openings should be multiples of 9 in. For instance, in a window opening 4 ft. 6 in. by 4 ft. 6 in., if the window cill is started on the proper course the cill and head will work in without any straight joints. It would appear a very simple matter, but to work these in properly on all sides of the building is somewhat tedious, especially in order to make the windows balance outwardly and yet to get them in the proper position on the inside of the room. Another thing which detracts from the outward appearance of the building is to see the blocks work out in whole or half blocks on one side of the frames and in quarter and three-quarter blocks alternately on the other side. This also applies to door frames.

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* This was the pre-war price, but in any case the price must vary to some extent according to local conditions.—ED.

The following is an extract from the report of the Commission on Rural Housing appointed a year or so ago by the President of the Board of Agriculture :—

> " In fairness, however, to the builders of some of the concrete block houses that we saw, and in defence of the method itself, it must be added that we inspected one example of a number of such houses, which was entirely satisfactory, the houses being pleasing in appearance, well-proportioned (a result not always easy to achieve in handling a unit so large as the ordinary concrete block), free from cracks, and thoroughly dry inside.
>
> " In building houses of concrete blocks it is important that the lengths of the walls and the sizes of the openings for door and window frames should be, so far as possible, exact multiples of the size of the blocks. The actual design of the concrete block has not been thought out so well in this country as in the case of a patent block used in Sweden, which provides for almost continuous air space. Hitherto blocks have usually been moulded with an air space in the centre, the inner and outer portions being connected at the ends. If the concrete is porous, damp is likely to strike through these solid portions; for this reason the method of laying double slabs on edge, so as to form a wall with a continuous cavity is being adopted in some places, and this method, if the work is carried out properly, is calculated to ensure a dry wall, even with concrete that is slightly porous. If, however, double slab walls are necessary, in order to obtain a satisfactory result, there cannot be much economy, in ordinary circumstances, in such a wall as compared with brickwork."

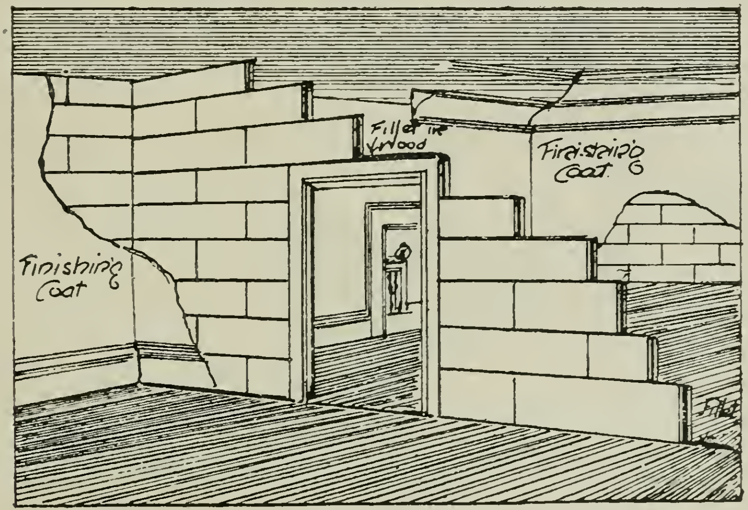


Fig. 19. View showing a Room formed with Partition Slabs.

These gentlemen visited different estates in this country, and it will be seen from this extract what their opinions were; but concrete has been more extensively used since this report was made, and vast strides have been made in all directions.

It may also be noted that after once setting a building out so as to work in windows and doors to suit the appearance of the blocks, that it is a simple matter to set to work on the next building, but it is always best to work them out to a 1-in. scale.

Fig. 13 shows a view of the foundations, etc., of a cavity wall built with 18 in. by 9 in. by $4\frac{1}{2}$ in. blocks. This needs little explanation. Upon the ordinary concrete footing a block is laid flat ways. This is done so as to be able to get a level bed to start work upon. Then all is plain straightforward working. The blocks are laid in cement compo, the joint between each block being $\frac{1}{8}$ in. to $\frac{3}{16}$ in. Each course shoud be pointed up and grouted with very fine grouting. This will make a good sound job and will stand the test of time.

In *Fig.* 14 a section is shown of the hollow blocks, and the method of building with them. The joints between the blocks are not more than $\frac{3}{16}$ in., and when laying them care must be taken to clean all jointing material from the holes in each block. This is to ensure a perfect air circulation.

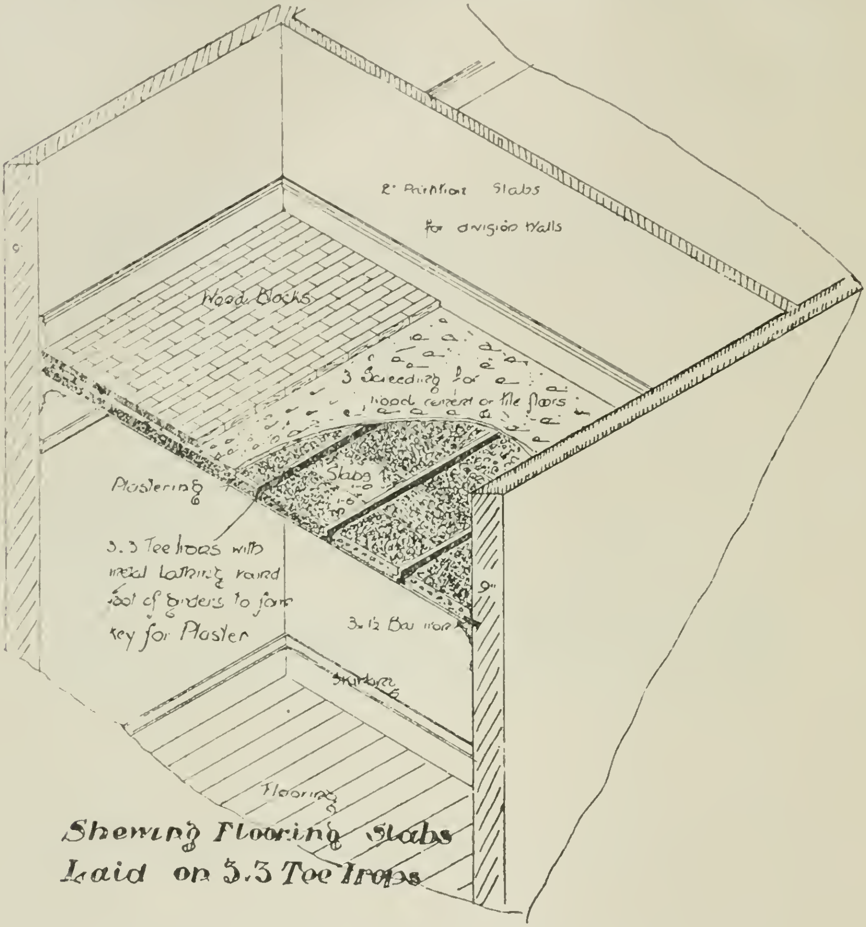
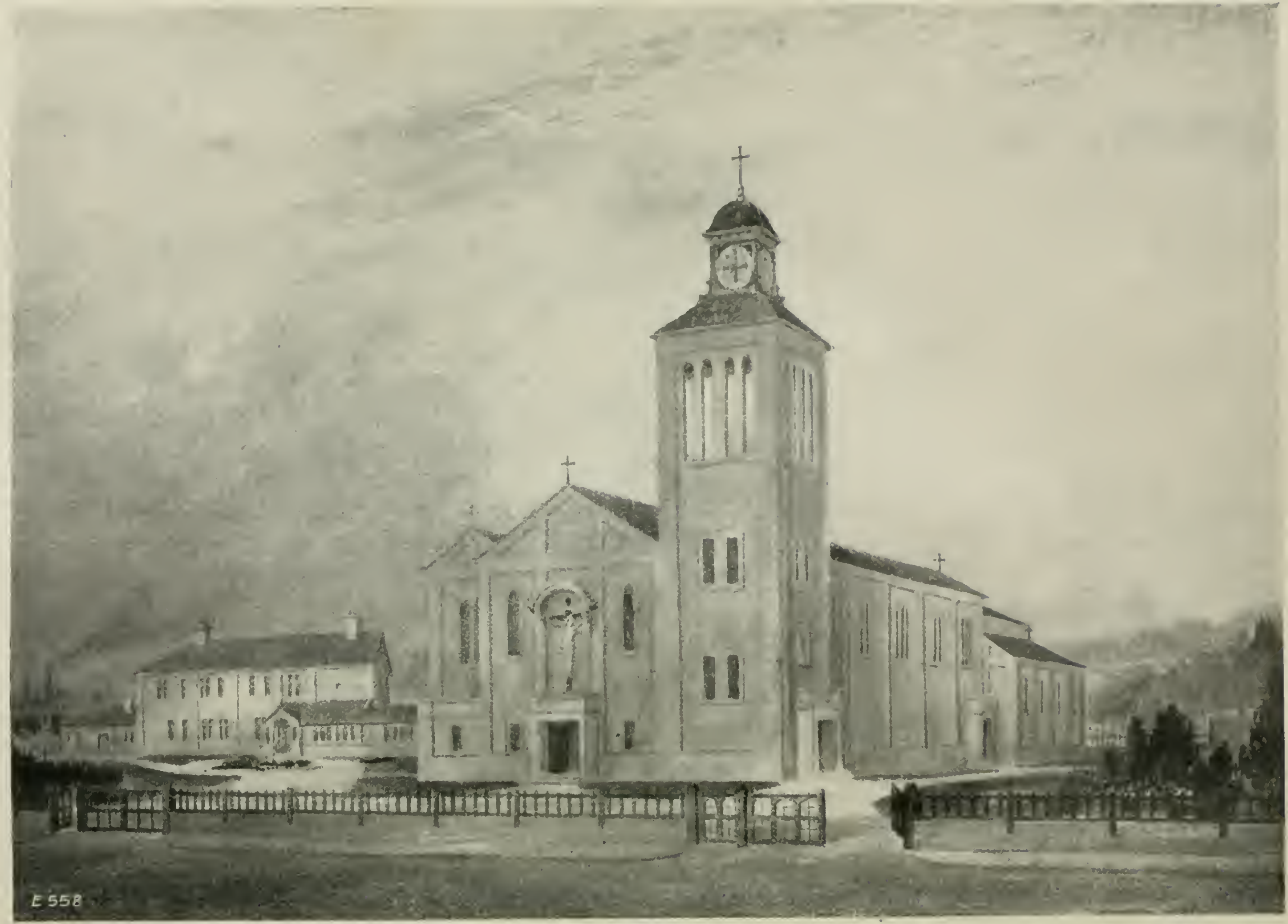


Fig. 20. Method of Forming a Floor with Concrete Slabs upon Tee-Irons.
(These slabs can be made upon a partition slab machine.)

(To be concluded.)

63x



Reinforced Concrete Church of Saint John the Evangelist and Saint Mary Magdalene, with Clergy House, Goldthorpe, Yorks.
Consecrated 18 May, 1916.
(See page 655 for description.)

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

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EDITORIAL NOTES.

THE CONCRETE INSTITUTE—THE PRESIDENTIAL ADDRESS.

The Concrete Institute has, indeed, been fortunate in the Presidential Address delivered on November 23rd by Mr. Wentworth-Sheilds, M.Inst.C.E. The address is by far and away the most useful one, appropriate to present conditions, that appears to have been presented to any of the technical institutions at the opening of the present winter session of 1916-17. It deserved an audience far wider than that of the Concrete Institute, for it claims the attention not only of everyone concerned professionally or industrially in concrete and constructional engineering, but in all forms of engineering in the widest sense, in architecture, surveying, and the kindred technical professions. It is to be hoped that the Institute, instead of relegating this address to its Transactions, which may only appear at some distant date, will *immediately* print and issue it to its members and to a wide range of the institutions, technical bodies and libraries concerned, and try to obtain for it that publicity in the Press that it merits. Not least among those associations who should study the paper are those concerned in representing the interests of the skilled artisan.

Nothing that we can say in these columns can accentuate the arguments of the President of the Concrete Institute, so ably put in his presidential address, which forms the first article of this issue in a somewhat abbreviated form. There is no portion of this address which should not have its opportunity for public consideration. But if we might be allowed to dwell on certain special features indicated in the address, we think that the first place should be accorded to the question of practical economy as advocated by Mr. Wentworth-Sheilds, and the second to the crying necessity of scientific research and the co-ordination of problems that require investigation.

Practical economy and research work can be put in hand promptly, and the results should be apparent almost immediately, certainly within the shortest period of two or three years. And apart from their importance it is for this reason that these two features should be accorded precedence in contemplating the presidential address.

But education similarly calls for immediate consideration. In dealing with this question, however, it should not be forgotten that it may take two or three years to devise suitable schemes for obtaining the education that is essential, and half a generation before even the first-fruits of such an educational scheme may be observable.

As to this whole question of education, from the technical and economical point of view, there is, however, one word that we should like to say that we do not believe to have been touched upon in the address. It is to emphasise that in the pre-war days, and equally at the present moment, learning of any description and knowledge based upon education and thorough investigation, are "unfashionable." It is not "good form," at the board school or in the public school, to work. Workers at the technical schools rank as "cranks." To discuss points of technical interest, to exchange views on technical problems outside the lecture room is classed as "talking shop." It is considered an attribute of "prigs" and "bores."

An educational scheme of any description—elementary, secondary or technical—cannot possibly be successful until it is "good form" to be well educated and technically well-informed. Any scheme of education must break down if this all-essential characteristic of present-day thought is not boldly met. And the only means of boldly meeting it is for those who are highest in the land, for the Government, and for the leaders of our great professions and our great captains of industry—whatever their experience may have been in reaching high pinnacles without education—to approach this gospel of better knowledge and education in a wider and more modern spirit. Education and technical knowledge must become "fashionable."

SOME TECHNICAL POINTS IN THE CONCRETE INSTITUTE PRESIDENTIAL ADDRESS.

Some interesting technical matters were mentioned in the course of the address, and they are worthy of consideration by members of the profession as showing in which direction progress can be developed in the near future, both as regards scientific research and practical application. The investigations which are being undertaken by the Institution of Civil Engineers to ascertain the deterioration of timber, metal, and concrete in sea water should be of value to all engineers, and the report on this work will be awaited with interest.

It is satisfactory to note that the Concrete Institute has drawn up a scheme for testing various concrete aggregates to ascertain the best way of using these, and it is hoped that the excellent scheme will be materialised as quickly as possible. It would be a great advantage if the tests could be arranged in such a manner that data could be drawn up for aggregates which are obtainable in various parts of the country as distinct from the very general classification that is now usually adopted. At the present time the engineer who is called upon to design and specify concrete work in a district removed from his own particular locality will often experience difficulty in obtaining reliable information as to local aggregates, and is usually compelled to carry out a few experiments at short notice or specify materials that are not local but with which he is familiar. The general classification of ballast, limestone, and so on, is apt to be very misleading. In the neighbourhood of the River Trent the engineer would not think of specifying Thames ballast, and yet data on the latter, which is easy to obtain, may prove very misleading as regards the former. Concrete is essentially a material which should be manufactured from suitable local aggregates, and reliable information applying to such local aggregates would be welcomed and fill a long-felt want of designers and builders. Information of the kind would assist in the most suitable materials being adopted and thus help forward the progress of good-class concrete work, which is essentially one of the objects of the Institute.

The important recent investigations on Portland cement made by Mr. Nathan C. Johnson, of New York, by means of microscopic examination of various concretes, were mentioned by the President, who states that the subject is of the first importance and calls for further research. With this view we heartily agree, and an exhaustive investigation should be promoted to see in what manner the chemical combination between the water and cement in concrete can be rendered more perfect. With regard to the opinion expressed by Mr. Johnson that the imperfect hydration is probably aggravated by insufficiency of water and mixing, it is interesting to note that in our last issue tests were given which indicated that the tendency in actual work is to use too much water, and it was shown that the increase in strength of the concrete was considerable when the percentage of water was comparatively low. It is difficult to reconcile such opposite views, and we base more importance on the fact that the tendency of the cement particles when mixed with water is to cohere into groups, owing to the surface tension of the liquid, and it is upon these lines that further experiments should be conducted. The fact that it has been shown that uncombined cement is likely to be a source of danger under certain circumstances, apart from the question of waste of good material, makes investigation absolutely necessary, and we feel sure that some measures will be taken in this direction by those interested in the welfare of concrete work.

The President wisely advocates the careful and systematic pursuit of purely scientific research in addition to what may be termed utilitarian research, because it is probably on these lines that the most important development will be made. Purely scientific research will often produce startling results, and the application of these, when practically possible, is such that tremendous strides are made in a very short time.

Many practical suggestions were made in the address in addition to the helpful remarks in connection with research work, and one of these related to the question of standardisation of factory and warehouse buildings in reinforced concrete to permit of the use of light steel form-work. We are in favour of standardisation wherever possible, and the suggestion is an excellent one if it can be practically applied. There are difficulties, however, which could not always be overcome even with the closest co-operation, and the comparison between the standard ship and the standard building is hardly applicable. The ship is not limited by such details as the question of irregular or limited site, the consideration of natural levels, approaches and aspect, and every building must be designed to suit the special needs of the owner as governed by the nature of the work to be carried on and the loads to be supported.

It can be truthfully said that no two buildings will be found to present exactly the same conditions, and thus a standard building would so seldom be applicable as to be uneconomical.

It may be practical to standardise certain individual members or units which could be assembled in some portion of the building and standard units of light steel form-work could be applied for these, but the use of timber for the remainder of the building appears to be unavoidable. Standard types of timber form-work designed on economical and practical lines could be evolved, and if these were published by the Institute they would be useful inasmuch as they would tend to decrease the waste of good material that often occurs through lack of experience on the part of those executing reinforced concrete work.

The use of machinery, which was dealt with, is also worthy of notice, and there is no doubt that contractors are waking up to the fact that the use of concrete mixers, block makers, and such like appliances tends to economical production and good-class work, and the successful man is one who keeps abreast of the times and takes advantage of modern invention.

PRESIDENTIAL ADDRESS.

By F. E. WENTWORTH-SHEILDS, M.Inst.C.E.

The Concrete Institute held its opening meeting for the session 1916-17 on Thursday, November 23rd, at 5.30 p.m., at Denison House, Vauxhall Bridge Road, when the Inaugural Address was delivered by Mr. Wentworth-Sheilds, M.Inst.C.E. Below we give the Address in somewhat abbreviated form.—ED.

INTRODUCTION.

The European war, horrible and devastating as its effects have been, has produced in this and other countries a wave of energy and enthusiasm for the better study of science and the arts and their application to industry. And this is not to be wondered at. There may be some who say: "Let us concentrate all our thoughts and energies on winning the war and on nothing else. Science and art are of little importance at the present time." But this is far from being the case. It is true that our first object must be to win the war, and that nothing must stand in the way of achieving it. But we now realise that this is, to a large extent, an engineer's war, and that science and the arts, industry and invention, play a most conspicuous part in it. In every branch of our Army scientific men have been pressed into the service to help with their knowledge and experience. The same remark applies to the new Government Department which provides the munitions of war, and to the many factories and organisations which are helping it. The chapter of history describing what the engineer, the man of science, and the captain of industry have done during the past two years will, I hope, some day be written. It will certainly be of extraordinary interest. And may I add that the special branch of work fostered by our own Institute will show some very bright achievements.

But there is a special reason why we must regard the work of societies like our own as particularly important at this time. When the war is over our next object will be to worthily maintain all that we have fought for, and to make impossible a repetition of such a devastating struggle. This is a matter which will call for greater and wiser efforts, individual and national, than even the winning of the war will have done. It must not be supposed that all we have to do is to "crush the Germans," and that then our troubles will be over. It is doubtful, to say the least of it, whether any nation can be crushed, and this is certainly not the object we have in view. We are giving our energies, our treasure, and our lives to break the military tyranny of the Central Powers and to establish the freedom of nations. And when peace is declared we must hold on to the strong position which every day we are gaining. To achieve this we must be ready to solve with energy and wisdom the many and serious problems which peace will undoubtedly bring; and in order to be ready we must prepare for them now. These problems will call for all the best brains that our country can give, and societies like ours will need to put forth all their strength. To-night I want to consider with you one or two of these problems, and how we, as members of the Concrete Institute, can play our part in their solution.

AFTER-WAR PROBLEMS.

The immensity of the problem involved in resuming, after the war, our usual commercial life will be realised when we consider that Great Britain alone has been diverting the activities of over 10,000,000 men to unproductive, and, worse still, to destructive, purposes. To restore these activities to normal paths in face of these difficulties will be a task requiring energy, foresight, and wisdom on the part of every member of the community.

And how, then, are these difficulties to be met? In a word, they must be met by economy—economy, not only in the restricted sense of curtailing expenditure and denying ourselves the comforts and luxuries of life—but also in the broader sense of ordering each man's work in the way that Nature's laws direct, so that there shall be the least possible waste and the greatest possible output of things that are really valuable to the nation, to its character, its health, and its happiness.

SCIENTIFIC RESEARCH.

For many years we have been dimly conscious that most of our industries could be more economically worked if we gave more attention to scientific and industrial research; but it seemed to need the European war to make us take vigorous action in the matter. It must be owned that previously our achievements in this direction compared unfavourably with those of some other nations. The National Physical Laboratory was established in 1900; but, with a grant of only £4,000 per annum, its usefulness was necessarily limited. It is true that our Government has contributed to the funds of the Engineering Standards Committee and of the Imperial College of Science, both of which have done a certain amount of research work. But when we consider that the American Government has been in the habit of subsidising its Bureau of Standards to the extent of nearly £100,000 per annum our own national expenditure on such work seems to have been poor.

But in July, 1915, a special Committee of the Privy Council was formed with a strong Advisory Council, with Sir William McCormick, LL.D., as Chairman, and empowered to spend £25,000 in 1915-16 on scientific research.

This body has already done good work. It has helped researches which had been already undertaken by various scientific societies and private firms, and has encouraged new ones. A complete list of these is given in the Council's report for 1915-16. One research of great interest to ourselves is the matter of deterioration of timber, metal, and concrete in sea water, which is being investigated by the Institution of Civil Engineers. The Concrete Institute, too, has not been idle, and with the help and co-operation of the professors of several British universities and technical colleges it has drawn up a most useful programme of tests to ascertain the best way of using various concrete aggregates obtainable in large quantities in all parts of the country. Briefly the scheme is as follows: Concretes will be made from a variety of aggregates mixed in the familiar proportions of 1 : 1½ : 3 and 1 : 2 : 4. Others will be made equally rich in cement, but with the portions of sand to stones varied. These concretes will be tested for strength, permeability, and other properties. In this way it is hoped to discover not only the relative value of various aggregates, but also the most advantageous way of using them. It is evident that such a research will be of untold value to the designer, to the builder, and to the community at large.

Our Council have had several interviews with the Government Research Council on this matter, and are confident that we shall receive assistance from them in this good work. We shall also ask for assistance from those who are interested in this particular industry, and I am sure we shall not ask in vain.

There are, of course, very many other subjects for research which our Institute can usefully promote as soon as our funds and organisation will permit. Indeed, they are too many to mention here. But I will briefly allude to one or two which are of more than ordinary interest. One is a line of investigation which has been taken up by Professor Coker, of University College, London, and described by him early this year before the Royal Institution. He has taken advantage of the discovery of Sir David Brewster 100 years ago that transparent materials when stressed become doubly refractive.

Again, one of the most important recent investigations on Portland cement has been made by Mr. Nathan C. Johnson, of New York, and published in the *Engineering Record* and in *Concrete*. By means of the microscopic examination of various concretes, he has ascertained that, generally speaking, the chemical combination between water and cement in mortar or concrete is exceedingly imperfect, and that only about 25 per cent. of the clinker is properly hydrated. He suggests that an enormous economy could be effected if this could be improved, as probably the 75 per cent. of uncombined cement is useless except as a pore filler, which for this purpose might with advantage be replaced by a stronger and cheaper material. He further shows that although this want of proper hydration is probably aggravated by insufficiency of water and of mixing, it is difficult in our present state of knowledge to avoid it. He throws out, however, some suggestions for possible improvements in this respect, and gives results of his own investigations. He points out that one impediment to proper hydration, as revealed by the microscope, is the tendency of the cement particles, when mixed with water, to cohere into groups, and thus avoid proper contact with the water, owing to the surface tension of the liquid itself. By the addition of certain other liquids, such as alcohol or ether, to the water the surface tension is reduced, and the cement particles are better dispersed in consequence. The practical advantage of such added liquids is shown in testing the crushing strength of concretes made with and without the addition of such liquids. For instance, with 5 per cent. amyl alcohol added to the mixing water, the strength of the concrete was increased about 70 per cent. at two months. It is not yet possible to point to any such substance which can be added to concrete economically, and without fear of detrimental effect, but it is clear that the subject is of the first importance, and calls for further research.

This is the more evident when we consider that the uncombined cement in a concrete is not only wasteful, but may even, under certain circumstances, be dangerous. This is clearly shown in a paper read by Mr. A. H. White before the American Society for Testing Materials. He describes investigations and experiments that seem to show that concrete, if alternately wetted and dried, is made to expand and contract, the net result being a gradually increasing expansion, and that if the process is repeated often enough disintegration may result. This disintegration is explained by him as follows: When water enters into the pores of dried concrete it combines with cement clinker which has as yet been unaffected. The result is that the concrete is expanded and the pores filled up, whereupon the action ceases until the concrete is dried again. Then the concrete once more becomes porous, and on re-wetting the expanding action is repeated. It is rarely, of course, that deterioration from this cause becomes serious in practice, but instances of such deterioration are not unknown, especially in the case of marine works and of pavements exposed to weather. They can probably be guarded against by the use of some protective coating, but this again is a matter which requires investigation.

The researches to which I have here alluded may all be classed as industrial, in that they may be expected to introduce economies in some industry (the building industry in these cases) within a measurable period. It is important that researches which are more purely scientific and less utilitarian should not be neglected. Their educational value is very great, and, moreover, their application to industry is probably only a matter of time and invention. Witness the case I have just cited of Professor Coker's application of the phenomenon of double refraction. Such purely scientific researches cannot, perhaps, be undertaken by societies like our own. But they ought to be carried on in every important laboratory and encouraged by grant of public funds.

On the other hand, industrial researches, those, namely, which may be expected to produce quick and practical results, should be undertaken under the guidance of men who not only have scientific knowledge, but who are also acquainted with the actual working of the industry for whose benefit the research is needed. To carry this out effectively means co-operation between the laboratory and the works, or, say, between the professor and the manufacturer. It means even more than this, namely, co-operation between various manufacturers who have hitherto been inclined to look upon each other as rivals, and to conceal from each other any knowledge and experience they may have gained. In this connection it is encouraging to read in the annual report of the Advisory Council on Research that "some manufacturers, at any rate, are beginning to realise that their most numerous and dangerous enemies are not their fellow-countrymen, but powerful combinations of manufacturers in other countries supported by every device of rate and tariff that their Governments can provide." And again, "In the numerous conferences we have had with representatives of different industries we have been impressed with the spirit of co-operation which is growing up and the willingness to accept our suggestions for the initiation of research for the benefit of the trade as a whole."

EDUCATION.

Although a great deal has been done in this country to improve the system of primary education for our working classes, it is evident that more remains to be done if we are to continue to hold our proper place among the nations in social and commercial life. The State now undertakes and insists upon the education of children up to the age of fourteen. Unfortunately, a large number then take up blind-alley occupations which offer them high wages but no training, and leave them two or three years later almost incapable of learning anything which will be of real value to them in after-life. Even when a boy is apprenticed to a trade at sixteen years of age he is not taught as he should be. It is true that in all our large towns evening classes are established at which he can learn many useful things, but most boys are too tired to derive benefit from lectures after having been at work for ten hours or more. It is generally felt that some better system is needed, under which a lad will continue his education, and not interrupt it just at the time he needs it most. The difficulties in introducing such a system are that it will involve increased expenditure to the parents or to the State, or both, and that it will produce a shortage of labour. To get over the latter difficulty it has been suggested that we should adopt some such scheme as has been successfully carried out at the School of Pennsylvania, U.S.A. Under this arrangement a four years' course of training is given to a youth after he leaves his primary school at the age of fourteen. The first year is spent wholly in the trade or continuation school, and the boy specialises in those subjects which will best fit him to take up his trade in the shop. The next three years are given partly to school and partly to shop work. During the time that the school is in session each boy attends every alternate week, the remainder of the weeks being spent in the shop. The special point of the scheme is that the boys are paired in each trade, so that while A is in school B, his mate, is in the shop, and vice versa. The scheme is, in fact, a half-time apprenticeship without the difficulties which attend the work of a single boy working half-time, *i.e.*, for so many hours a day or so many days a week. The work of the two paired boys has been proved by experience to be at least equivalent as regards value of output to that of the single boy working full time.

We have not yet outlived the day when education was looked upon as a privilege of the upper classes, and when it was considered that national schools would have a demoralising influence upon the poorer citizens and produce among them discontent and even inability to perform the humbler kinds of labour. It is scarcely yet recognised that there is no sort of labour which cannot be made more interesting and more productive by education and scientific training, and, again, that if our civilisation is to be a real national progress, the development of the mental and spiritual faculties of each of us must be an important item in our national programme. When these facts are clearly recognised, the country will no longer grudge the necessary expenditure on training its boys and girls more thoroughly than it does now, and it is certain that such expenditure will be amply repaid.

Passing to the question of secondary education, every member of our society will be in cordial sympathy with the movement to emphasise the importance of science in public schools and university education, and to abolish the absurd proportion of time given to the study of Latin and Greek. We do not for a moment, of course, wish to do away with the cultivation of humane letters, but that our two senior universities should practically compel their students to spend an enormous part of their school hours in learning subjects which the majority of them cannot appreciate, and from which eventually they derive little or no benefit, is a national scandal.

Fortunately the newer Universities are more alive to the importance of science, and less hampered by the tradition which has made it the Cinderella of school subjects. Even here, however, there is room for further usefulness. If science is to be really and seriously cultivated in this country, it should be taught at our Universities to every member of our leading professions, to our Civil Servants, and also to those who are to take a leading part in commerce and industry of all kinds. But the influence of our universities should not cease at this point; they should be in constant touch with the life and work of the men they have trained. It is perhaps unfortunate that the professors of our British Universities are in many cases schoolmasters and nothing more. In other countries it is not considered desirable that students should be taught by a man who does nothing but give lectures. The professor is encouraged to keep in touch with the world of commerce in various ways. He is permitted, or in some cases obliged, to act as consultant on practical work. At one University in America, commercial firms are invited to bring special research problems to be investigated by the college staff, who are bound to secrecy, and, on the other hand, participate in any success which the investigation may produce. Such intimacy between school and business is sure to be of the greatest benefit to both.

ECONOMIC INDEPENDENCE.

The war has strongly impressed another idea upon us—namely, that it is consistent with true economy that we should make use of our own national and Imperial resources rather than be entirely dependent upon other nations for the materials and manufactures which we use day by day. "When war broke out," says the report of the Research Council, "our supply of dyes and glass was practically cut off. We were dependent on Germany for magnetos, for countless drugs and pharmaceutical preparations, even for the tungsten used by our great steel makers, and for the zinc smelted from the ores which our Empire produced." I am glad to add that vigorous measures were taken, with liberal assistance from the Government, to remedy this state of things. But that such a thing could happen has given us food for thought. Our easy-going theory of the past suggested that we should buy in whatever happened to be the cheapest market and pay for the goods with something that we could produce more cheaply still. The drawbacks of this practice are now fairly obvious, and, moreover, we are beginning to discover that we can produce many things quite as cheaply as other nations if we will only take the same trouble.

A very striking instance of this fact is constantly being brought to the notice of the members of this Institute.

In 1913 the value of timber and wood goods imported from our Colonies and from foreign countries (mostly from the latter) was over £37,000,000. A very large proportion of this timber was used in building construction of all kinds, and yet we know that a great deal of it could be replaced by steel and concrete manufactured at home, and that the resulting structures would be cheaper and more permanent. The price of timber, which is now three times as great as it was in 1913, is forcing this subject upon our attention, and it is safe to say that when the war is over and prices are down to more normal figures, concrete, plain and reinforced, will largely displace its foreign rival, and that every architect, engineer, and builder will be expected to be well acquainted with its use.

In this connection it may be noticed that an important item in the cost of reinforced concrete work is the provision of the form-work, which is usually made of timber. Indeed, this type of construction has been adversely criticised on the ground that it is necessary to erect a timber building before the more permanent structure can be built up, and that the timber so used is of little or no value afterwards, and is practically wasted. There is no doubt that designers could avoid a great deal of this waste by planning their buildings in such a way that the form-work can be used again and again. We have heard a good deal lately about the standard ship, and it has been suggested that shipbuilding could be enormously cheapened by constructing vessels to one or two standard designs. Why should not we have in the same way a standard factory or warehouse in which the spans and scantlings of the beams should conform to a pattern? Such a design would admit of light steel form-work being economically used, and would mean a saving of labour and material, both to the designer and builder. It only requires closer co-operation between all connected with the industry to bring it about, and I think the Concrete Institute would do a good work if it were to lay down such a standard.

INCREASE OF OUTPUT.

One of the great difficulties which we have had to encounter in our endeavour to obtain economical work has been the restriction placed by the workmen themselves through their trade unions on the amount of their output. To Mr. Lloyd George belongs the credit of having induced them to some extent to forego these restrictions, although they are by no means abolished. Unfortunately, the Government has promised that after the war is over all such restrictions shall be re-established. In the name of common sense let us hope they will not. The attitude of working men in this matter has been foolish and suicidal in the extreme. The result of the policy is clearly seen by comparing our census of production of 1907 with the American census of 1909. In almost every trade the American workman produces two to three times as much as the Englishman. No one would suggest that the American is cleverer or stronger than our own artisan. It is simply that the point of view of the American workman is, or at all events has been, entirely different to that of the British. Our men seem to labour under the mistaken notion that in every workshop or group of shops there is only a limited amount to do, and that if any one man voluntarily increases his day's work he is depriving some other man of employment. This, of course, is an entire fallacy. Indeed, it may be said that the opposite is the case, and that the industry which can produce the largest output at a given expenditure will be the one which will be able to employ the greatest number of men. On the other hand, many intelligent working men will reply that they are quite aware of this, but that if they use their best efforts to increase production the employers, by refusing to raise wages and by cutting down piece-work prices, prevent the workman from getting his fair share of the added wealth. Unfortunately, there is some truth in this criticism. The question was dealt with by Mr. Gerald Stoney, F.R.S., in his address as president of the Engineering Section of the British Association at its meeting this summer. He pointed out that at present the most highly skilled men are paid by time, and thus earn considerably less than others of more mediocre attainments, who are paid by the piece. This is an arrangement which seems to be neither fair to the men themselves nor advantageous to the works as a whole. Again, coming to the question of piece-work prices, Mr. Stoney points out that it has been customary to cut down the price when a workman's earnings prove to be more than 50 per cent. in excess of what he would make if paid by time. This, too, is unfair and unwise, and the practice is responsible for the wilful limitation of output. He suggests that to some extent piecework prices should be fixed by a special department, and that they should not be cut down except in extraordinary circumstances, and certainly not because the man happens to be earning good money. There is no doubt that too much stress has been laid in the past by employers on the desirability of keeping wages low, and we are beginning to realise that reasonably high wages are a positive advantage to a manufacturing concern, provided that they are accompanied by a large output.

BETTER USE OF MACHINERY.

Another economy which needs to be developed in this country is the more extended use of machinery and of better machinery. In many of our workshops the machines are old-fashioned and insufficient, but their owners have hesitated to abolish them for various reasons. Conservatism, no doubt, has been partly responsible for this lack of enterprise, and perhaps a more important cause has been the difficulty of obtaining a proper output from machinery owing to the lamentable restrictions imposed by the various trade unions, who seem to be possessed with the groundless fear that the use of machinery will lead to unemployment. The war has done much to change this, and in many workshops new plant has been laid down in order to meet the imperative demand for increased output. The resulting economy in production has been brought home to manufacturers, and it is not likely that the lesson will be forgotten. Even in the building industries, in which we are more directly interested, the introduction of new machines has been very noticeable. On many works such appliances as concrete mixers, block-makers, wood-working machinery, and all kinds of elaborate cranes and conveyors are used, where formerly the work would have been done by hand. The advantages both in increased output and in the quality of the work done have been very great, and further invention will undoubtedly extend these improvements.

SCIENTIFIC MANAGEMENT.

Among the many ways in which science can help industry is the methodical arrangement and teaching of hand labour. For generations the apprentice has been taught his trade by being put to work along with the older hands, so that he may learn by observation, with perhaps some imperfect explanations. The limitations of this system have been shown in a most interesting way by Mr. Winslow Taylor in his book on "Scientific Management." He shows that very careful measurements and records are needed to find out how a man can do any piece of handwork to the best advantage.

RELATIONS BETWEEN EMPLOYER AND WORKMAN.

But even if the workman is scientifically taught his trade, in order that he shall increase his efficiency to the utmost, it is necessary to gain his goodwill, and this perhaps is the most difficult problem of all. A paper full of interest on this subject was read by Sir William Lever at Manchester a month ago. Its author is well known for the large amount of time and thought and money he has spent on the welfare of his workmen, and his remarks are therefore worthy of special attention. He points out that the old idea that labour is merely the paid tool of capital has got to go, and that the attitude of obstinacy and distrust shown by working men towards their employers will not be changed merely by giving them higher wages and better conditions of life. They have shown that under certain circumstances they are capable of high ideals and of great self-sacrifice. This has been remarkably evident in the way they have fought for their country, although many have not as yet applied this spirit of self-sacrifice to the ordinary work of commercial production. This, he thinks, is largely due to the fact that they have been looked upon as machines rather than human beings. The arrangement under which all profits or losses go to capital is not a healthy one, and ignores the psychology of the workmen. He suggests that in every industrial concern there ought to be a ladder from the humblest position to a seat on the board of management, and that both profits and losses should be fairly divided. On both sides there must be give and take. Capital must not expect labour to give up trade unions and the privilege of grumbling for better conditions, and labour must not expect capital to give up control and discipline. In a word, he advocates co-partnership, and deplores the fact that trade unions have opposed it. He regards it not merely as a system for producing high wages and large profits, but as a spirit which will humanise the relations between man and man, and which by combining the democratic with the individualistic attributes of human nature will result not only in higher total earnings, but in greater efficiency, happier life, and improved mental conditions.

BANKING FACILITIES.

The provision of capital for new undertakings is a matter in which, perhaps, a few of our members can assist, but none the less it is of very great importance to us, since the engineer and architect, generally speaking, control its expenditure, and I need make no apology for alluding to it here. It is far from satisfactory to learn that out of £250,000,000 subscribed in this country to capital issues in 1913, less than £50,000,000 was invested at home. During the war, however, an extraordinary number of new factories have been started, and after it is over we shall probably find that the relative importance of our various industries will have altered somewhat, and we shall be called upon to produce many articles for which we have hitherto been dependent upon foreign countries, and also to sell to new customers. Whether as a nation we shall be able to meet this demand will depend to a large extent upon what facilities can be given for the finding of capital for new ventures. Such capital will be required not only for starting new factories and business concerns, but also for financing sales to possible customers like the Russians and the Italians, who are accustomed to ask for long periods of credit. The facilities offered by our British banks in the way of providing money for such undertakings has been severely criticised by many authorities, and notably by Messrs. Farrow and Crotch in a little book which they have recently published called "The Coming Trade War." They compare our modern banks very unfavourably with the so-called German system, and again with the Scotch banks of the eighteenth century, which they say did so much to assist the extraordinary commercial and industrial development of that country 200 years ago. The authors point out that we need a banking system which shall favour not the richest consumers, but the largest employers of labour, which, by giving cash discounts under suitable safeguards, shall enable our merchants and manufacturers to sell in countries where long credit is required, and which shall further assist them with all kinds of information.

In response to such criticism the Board of Trade has appointed a strong committee, with Lord Farringdon as chairman, to report on the matter, and they have recommended that a British "Trade Bank" be established under Royal Charter with a capital of £10,000,000

INDUSTRIAL CONSULS.

It will be noticed that the report of Lord Farringdon's Committee, which has just been quoted, develops a suggestion which has been made elsewhere, that instead of depending so largely as we do at present on our Consular Service for information about foreign markets, we should establish a similar service organised by and for British men of business. It is certainly notorious that our Consular staff in the past has consisted largely of men who, whatever their other qualifications may be, know little or nothing of commerce. It would certainly seem that, whether employed by the Government or by such an institution as the British Trade Bank, such representatives should be British born and men with good business training. In this connection it is interesting to note what has been done by the American "Bureau of Foreign and Domestic Commerce," a description of which was recently given in an American magazine by Mr. W. C. Redfield, the Secretary of Commerce to the United States. He tells how the Bureau recently secured to a big smelting and refining company the business of smelting Bolivian tin ores which hitherto had all been treated in Europe. It also succeeded in getting the Spanish tax on American coal withdrawn, with the result that exports to Spain were largely increased. Further, it secured contracts for American firms in Norway, Roumania, and Africa. It has ten commercial attachés in various capitals, all of whom are trained business men and who speak the language of the country in which they live, and who spend their whole time in building up American trade. It also engages a large staff of travellers, who specialise in certain industries. Before setting out on their journeys these travellers consult the principals of the industry they are to represent as to what they can supply, and while on their journey they communicate constantly with them through the Bureau, obtain samples of what is needed abroad, learn the special difficulties that have to be encountered, find out the methods of their competitors, and on their return see the manufacturers at home and give to them all the information they have acquired. It is interesting to note, too, that this Bureau of Commerce not only publishes frequent up-to-date reports, but also owns and manages the American Bureau of Standards, whose magnificent work in industrial research is more or less known to us.

I do not wish to suggest that British manufacturers have been wholly idle in this matter. For instance, the Associated Portland Cement Manufacturers and the British Portland Cement Manufacturers, which together provide about 95 per cent. of the total British export of cement, which in 1913 amounted to 750,000 tons, maintain permanently a representative in South America, where before the war a large market was keenly competed for with Germany. The representative in question is a trained chemist and works manager and good linguist. The same firms also send representatives to Australasia and India, and have organised works in British Columbia, Mexico, and South Africa. Such enterprise is highly commendable, but it is evident that only very large and wealthy firms can manage to keep such an efficient travelling staff, and that if British industries generally are to be enabled to sell their goods steadily new markets must be found for them by some organisation encouraged and assisted by the Government.

CONCLUSION.

We have now considered very briefly some of the problems which we shall have to face when the war is over, and how they can be solved by the exercise of national economy. We have used the word economy not only in the restricted sense of avoiding expenditure, but in its truer and larger sense of establishing the "law of the house," the law under which each man works not for himself alone, but for the community of which he is a member. We have seen that by using our powers in co-operation, as well as individually, we can do much more than we have in the past to produce those things which are really essential for the health and happiness of the nation and the Empire. We have dwelt on certain lines along which such co-operative efforts may be expected to produce great and beneficent results. We have considered the encouragement of scientific and industrial research, the lessening of our economic dependence on foreign nations, the more liberal use of machinery, the introduction of greater facilities for advancing money, the collection of information about new markets, the closer co-operation between employers and workmen, and perhaps most important of all the improvement of our methods of education. All these are matters of vital importance to the nation at this time. Moreover, they are matters in which the Concrete Institute is profoundly interested. In fact, we may say that it is with the concerns of national economy that we have been occupied during the few years of our existence. Economy is a matter that essentially appeals to us. The Charter of the Institution of Civil Engineers describes its members as those who direct the great sources of power in nature for the use and convenience of man. The racy American says that the engineer is a man who can do for one dollar what any fool can do for two. Both definitions contain a truth and an ideal which appeal to us all.

A glance at our past year's work will illustrate our interest in economy in the best sense. We have had six general meetings at which stimulating and thoughtful papers have been read and discussed. Our standing and joint committees have met regularly to solve such problems as the promotion of research work, the establishment of right relations between architect and engineer, the standardisation of measurements, advice about the methods of executing concrete work, and the correct interpretation of the laws relating to steel-framed buildings. All these matters represent an endeavour to introduce economy in building, and when it is remembered that building is one of our largest industries, and that one-tenth part of the nation's industrial output consists of buildings and engineering structures, it will be realised how important is the work which lies before a society like ours.

Again, we have seen that the Great War has taught us that to be fruitful our economy must include and be inspired by the spirit of co-operation. Our individualism has been a source of immense national strength to us, and I hope we shall never lose it. But we must also cultivate the spirit of mutual service between the State and the civilian, between employer and workman, between one profession and another. Among the members of professions we must include the manufacturers and traders, the captains of industry, from whom we expect great things at this time. The learned professions have been inclined in the past to look down on such men because they said their first object was to make profits. But why should it be their first object to make profits? Ruskin long ago pointed out that the merchant's first object should be to provide for his country, and that he should be ready, like the soldier, to die in the attempt to carry out this object if needs be. This may sound too good to be true, but I venture to say that it is right, and that we must expect all our merchants and manufacturers to take this view. The best of them have always done so. Our country will not keep the high place she has regained among the nations unless they do.

The war has had cruel and terrible results. There is not one of us who has not felt the sting of its destructive power. But strangely enough this fearful thing has opened our eyes, and has made us see many truths which had become dim. It has shown us a vision of what England and the British Empire can and must attain, and every man and every society of men must bear its part in realising the new ideal. Among those who will help to realise it will, I doubt not, be numbered the Concrete Institute.

THE VOTE OF THANKS.

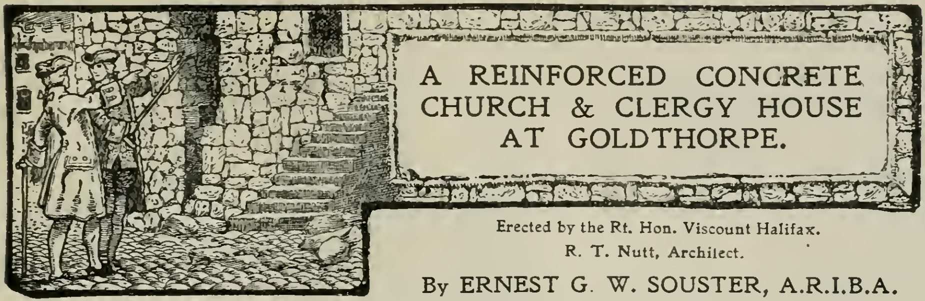
Professor Henry Adams, as the immediate past-President, said he had very great pleasure in proposing a hearty vote of thanks to the President for his address. It was a difficult matter to write a presidential address that should be interesting and at the same time not controversial, but he thought the President had steered a very happy course in what he had put before them. Although this was his first public appearance before them (the election was last May), the Council had had the advantage of his experience and services since that time, and they had been by no means small. He had already done a very great deal of useful work for the Concrete Institute, more particularly in connection with the Research Committee, of which he had told them a little that evening. At present it was only the beginning; he had not the slightest doubt it would extend to be a most important matter in the progress of the country at large. Only that morning he signed a memorial of the London Chamber of Commerce to the Government for the appointment of a Minister of Commerce. If ever it came about it would affect very largely many of the questions that the President had put before them that evening. It was well that engineers and architects should occasionally look outside the mere technical details of their profession, and the words they had heard that night had brought before them some of these outside matters—the general points that affected the welfare of the country at large and not only their own profession—and therefore he thought they might congratulate themselves very heartily upon what they had heard from the chair.

Mr. Edwin O. Sachs, F.R.S.Ed., in seconding the motion, took the opportunity of congratulating their new President upon his access to office and also to say a word of thanks to their outgoing President for the most excellent way in which he had presided over their meetings during the last two years, not only in the most able but in the most equitable nanner, in a period or at least the beginning of a period which was a very difficult one in the Concrete Institute. Professor Adams had had a long career of eminent public service, but he had excelled himself in those last two years. Turning to the address to which they had just listened, he thought he was right in putting it quite plainly that it was the best of the presidential addresses delivered this winter at any of the technical institutions, and he had had the pleasure of reading, or attending, them all up to date. It was a presidential address of far-reaching importance. It was a far "bigger" address really than they would expect at the Concrete Institute; it was an address, if he might put it in Press parlance. which certainly deserved full reporting in *The Times*. He hoped that the Concrete Institute, or rather the administration of the Concrete Institute, would use some endeavour to see that this address, which was so valuable and opened so many points, would have that publicity which it merited. They were only a small audience there that night, but he trusted that all their members would receive it with great promptitude and that it would not take long to reach their members not only at home but in the Colonies. To go into the details of the paper would lead too far, but the great outstanding feature in the gospel that was preached in it was research and co-ordination, and if the Concrete Institute could only do something to follow in the footsteps laid down by their President it will have done a great deal of good work in the coming year.

The resolution was put to the meeting and carried by acclamation.

The President thanked them most heartily for the kind way in which they had received the proposition. It had been a very great pleasure to him to write the address and to come there and give it to them. It was exceedingly nice of Professor Adams to have alluded so kindly to the little work he had been able to do so far. He was very glad that Mr. Sachs had mentioned the very great deal of work which Professor Adams had done. He did not know how many societies Professor Adams had been president of; he was an old hand at it; he had a new society every year to preside over. That accounted for the skilful way in which he was able to steer the Concrete Institute through some very stormy waters, and in some senses he was taking up the work at a much easier time than the Professor, owing to the fact that he had poured a good deal of oil on them. On the other hand, in some respects it was a very important time. The research work, which they were beginning, they hoped would blossom out into a very large and useful work. Without betraying any secret he might say that they had formally applied to the Research Council for a grant to carry out this particular research. That, of course, was a beginning, and he hoped, before many years had passed, they would be controlling many useful researches which were crying out to be finished. Once more he thanked them most cordially for their reception.

The meeting then terminated.



A REINFORCED CONCRETE CHURCH & CLERGY HOUSE AT GOLDTHORPE.

Erected by the Rt. Hon. Viscount Halifax.
R. T. Nutt, Architect.

By ERNEST G. W. SOUSTER, A.R.I.B.A.

In this country reinforced concrete has, so far, not been extensively used for church architecture, and, therefore, the following description and illustrations of a church wholly erected in that material should not be without interest.—ED.

THE use of reinforced concrete is now general for many purposes, and signs are not wanting that it will soon become the usual means of construction for factory and such-like buildings.

Whilst this fact is recognised by most architects, there seems to be a vague sort of belief that it is not a " proper " material for the better types of buildings, and that if it is used it must be covered up or hidden; and we therefore hope that the illustrations of the buildings here shown will help to dispel that belief.

Architectural magazines and congresses have periodic discussions on the formation of a new style that will express the needs and ideals of our own times, the æsthetic type of critic laments that our constructions are not expressed in our works; and although it is a moot point whether reinforced concrete will lead to a class of buildings quite distinct in style from anything that has been done before, it will undoubtedly alter the underlying plan and section.

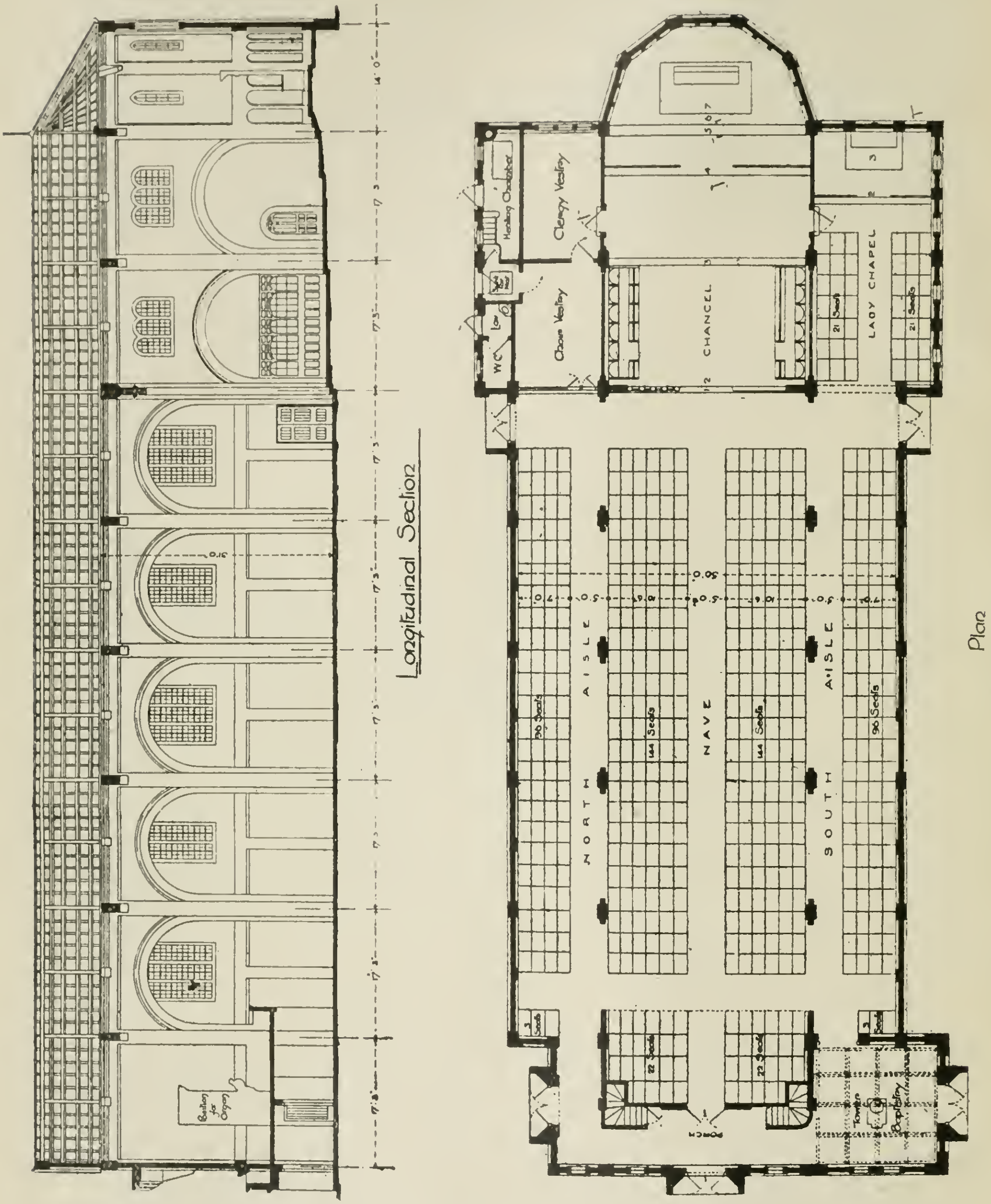
These buildings are therefore very interesting, as they furnish us with examples of buildings expressing the constructional lines of the work and at the same time possessing the character of the use for which they are erected.

The site on which the church is erected is in close proximity to a disused coal mine, and whilst it has been decided, and means taken to prevent coal from ever being removed from under the site, the possibility still exists that subsidences may occur, and very careful designing of the foundations and superstructure was necessary. After much consideration a monolithic building was decided upon, and the whole structure rests on a beam raft extending over its whole surface and capable of resisting fracture should subsidence of subsoil occur at any point or points.

A reference to the plan, *Fig.* 2, shows that the building is on the traditional lines of church planning, and consists of a nave 26 ft. clear span, with side aisles, giving a total width of 50 ft. The nave is divided into six bays, 17 ft. 3 in. long each, the western one of which is divided by a wall to form a porch below, whilst an organ and choir gallery over extends for its full width, and also projects about 4 ft. over the fifth bay.

The line of the concrete piers dividing the nave from the aisles is carried on into the chancel, which consists of two further bays of 17 ft. 3 in. each, flanked on the south by the Lady Chapel and on the north by vestries, heating chamber, etc., and finally terminates in a five-sided apse.

From a structural point of view the building consists of a series of piers and beams carrying the whole weight of the building, and stiffened by circular and arched members. Between these piers the walls are but 6½ in. thick, but where window and door openings occur they are thickened out for both



Figs. 1 and 2. A Reinforced Concrete Church and Clergy House at Goldthorpe, Yorks.

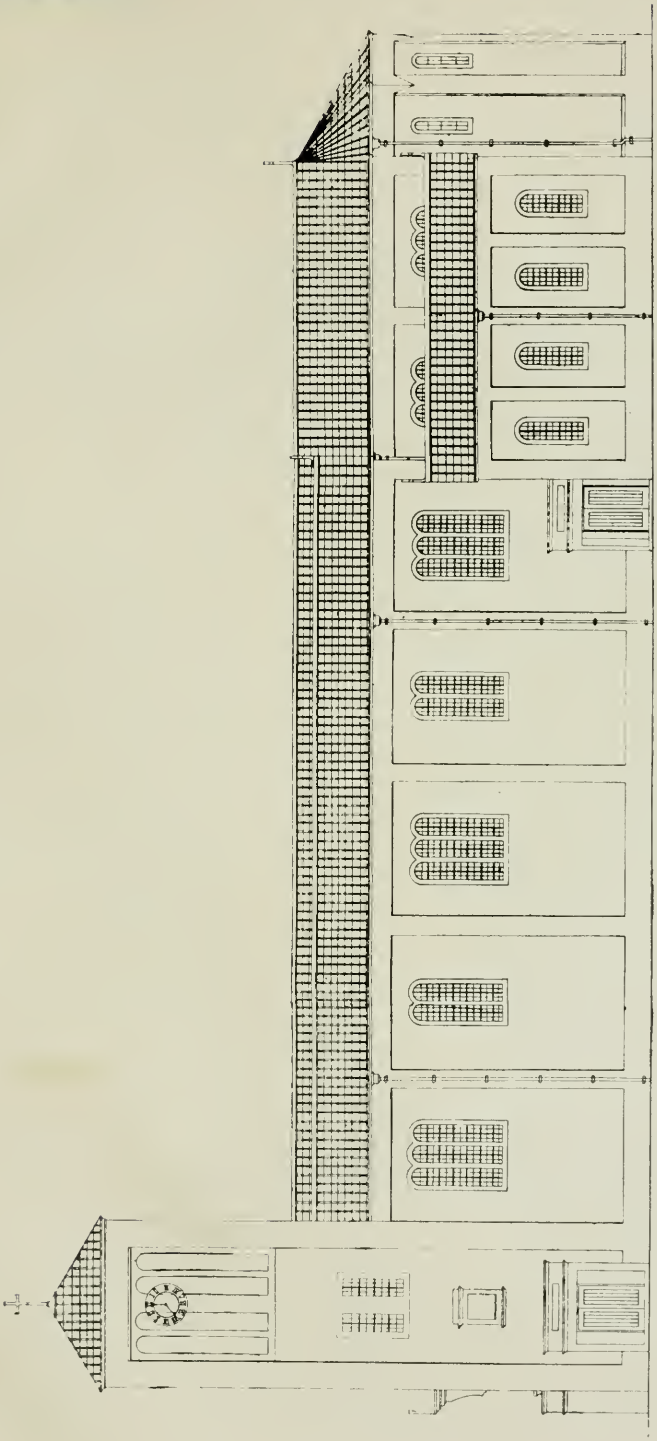


Fig. 3. South Elevation.

Reinforced Concrete Church at Goldthorpe, Yorks.

structural and architectural reasons. Externally the walls are left as formed, so as to bring out the aggregate of shingle and sand, giving texture and tone values, and the openings are finished with wood floated cement and sand architraves. The effect is, as will be seen from *Fig.* 13, quite pleasing, and the general asperity of treatment gives an added value to the finer work around the entrance. The crucifix and the hood above it are of reinforced concrete, and the effect aimed at is enhanced by the use of different colours in aggregates.

Internally the walls are plastered and, but for very simple mouldings, are quite plain, and thus form a background for the

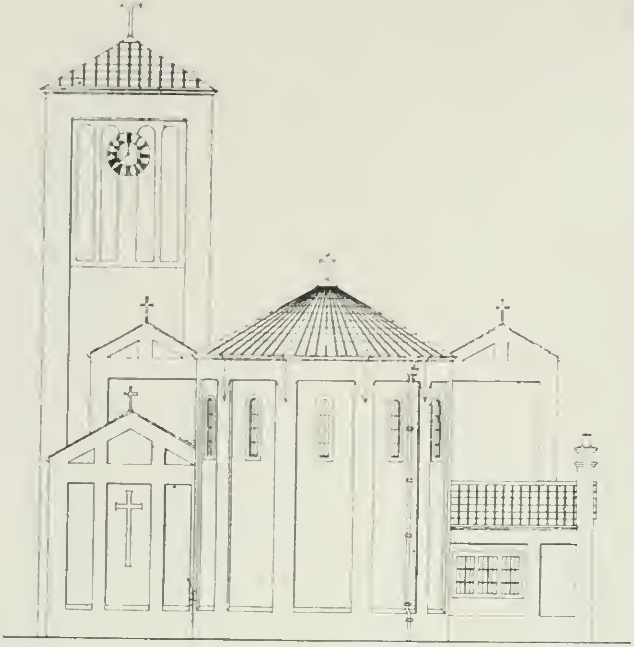


Fig. 4. East Elevation.
Reinforced Concrete Church at Goldthorpe, Yorks.

statuary, paintings and focal points of the building, which are richly decorated. The roof of the building is of deal boarded (toned to colour of oak) and finished externally with red tiles, as is also the tower, which forms one of the most distinguishing features of the composition.

This tower (see *Figs.* 3, 4, and 5) consists of piers at the corners with a thin wall filling, and at the belfry level the wall is pierced by four long narrow openings on each face. These openings are and will be left open in order to avoid excessive wind pressure. On the roof of the tower a square domical finished clock chamber (as an after thought) has been formed, which is covered with copper.

The ground floor of the tower is designed as the Baptistery, and the font (see *Fig.* 17), with the steps to it, are formed of concrete, partly left rough and partly finely finished.

The use of concrete of different textures and colours, gained by mixing Belgian black sand and ordinary coloured

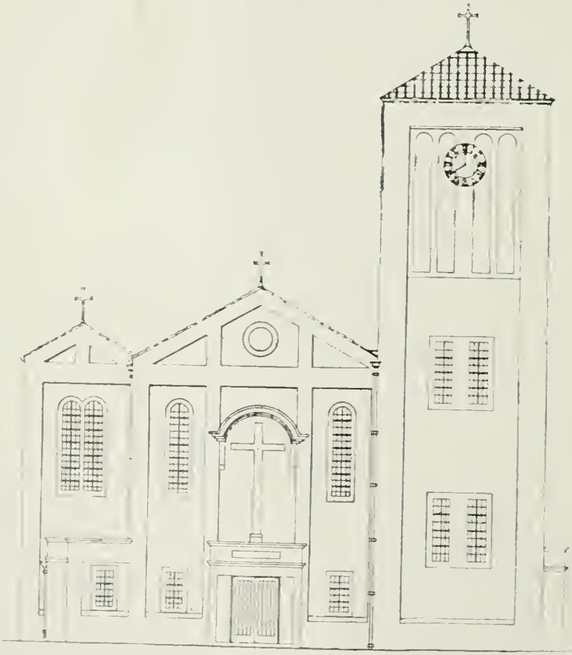


Fig. 5. West Elevation.
Reinforced Concrete Church, Goldthorpe, Yorks.

sands, is carried into the whole of the church finishings excepting the pierced dwarf wall under arch with iron gates, demarking chancel, flanked on either

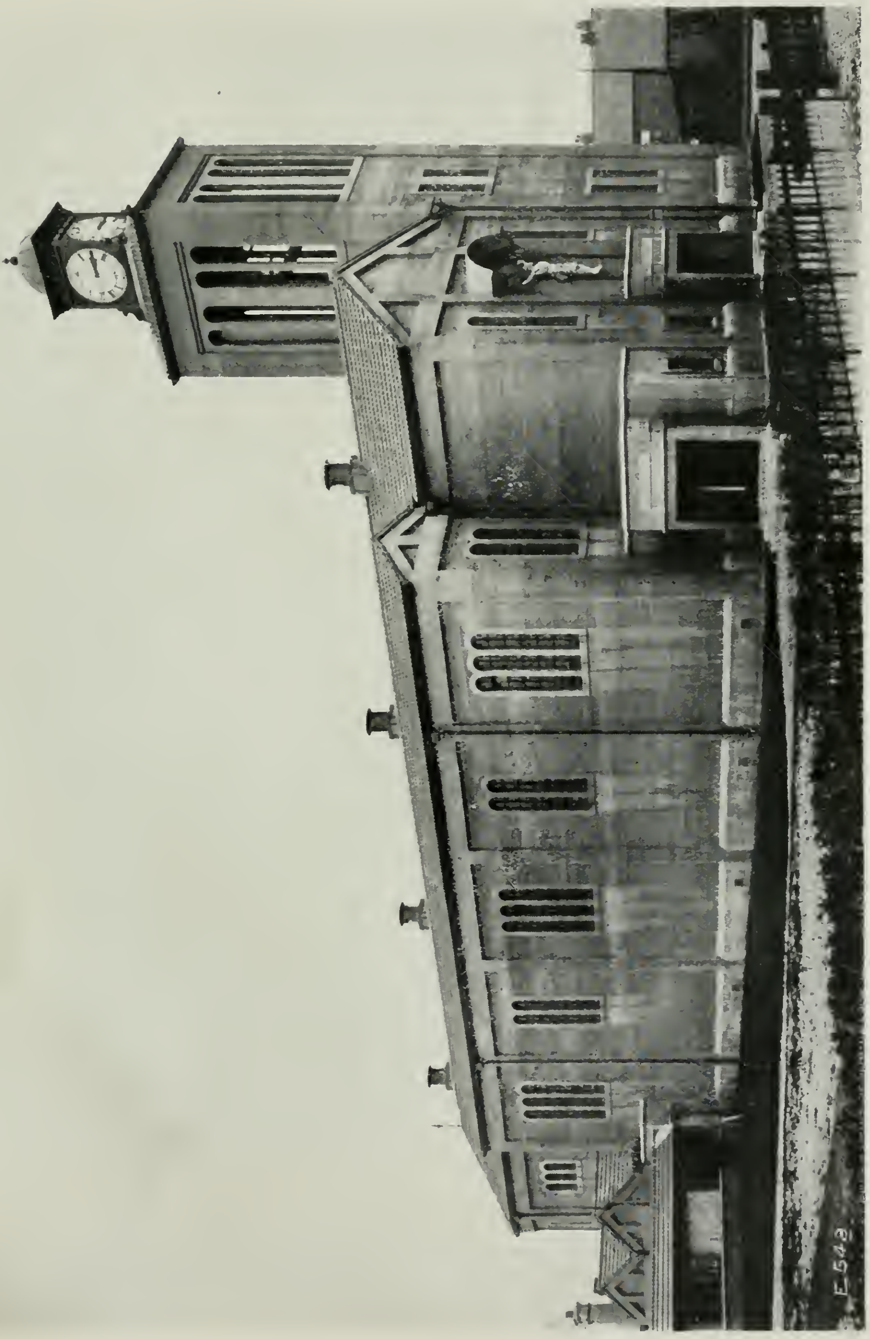


Fig. 6. General View of Complete Building.
Reinforced Concrete Church, Goldthorpe, Yorks.

side by two ambones or pulpits in Yorkshire stone, as shown in *Fig. 7.* The central point of the whole building is, however, the baldachino over the altar, which rises from the floor to within a few feet of the roof (see *Fig. 7*) (view of

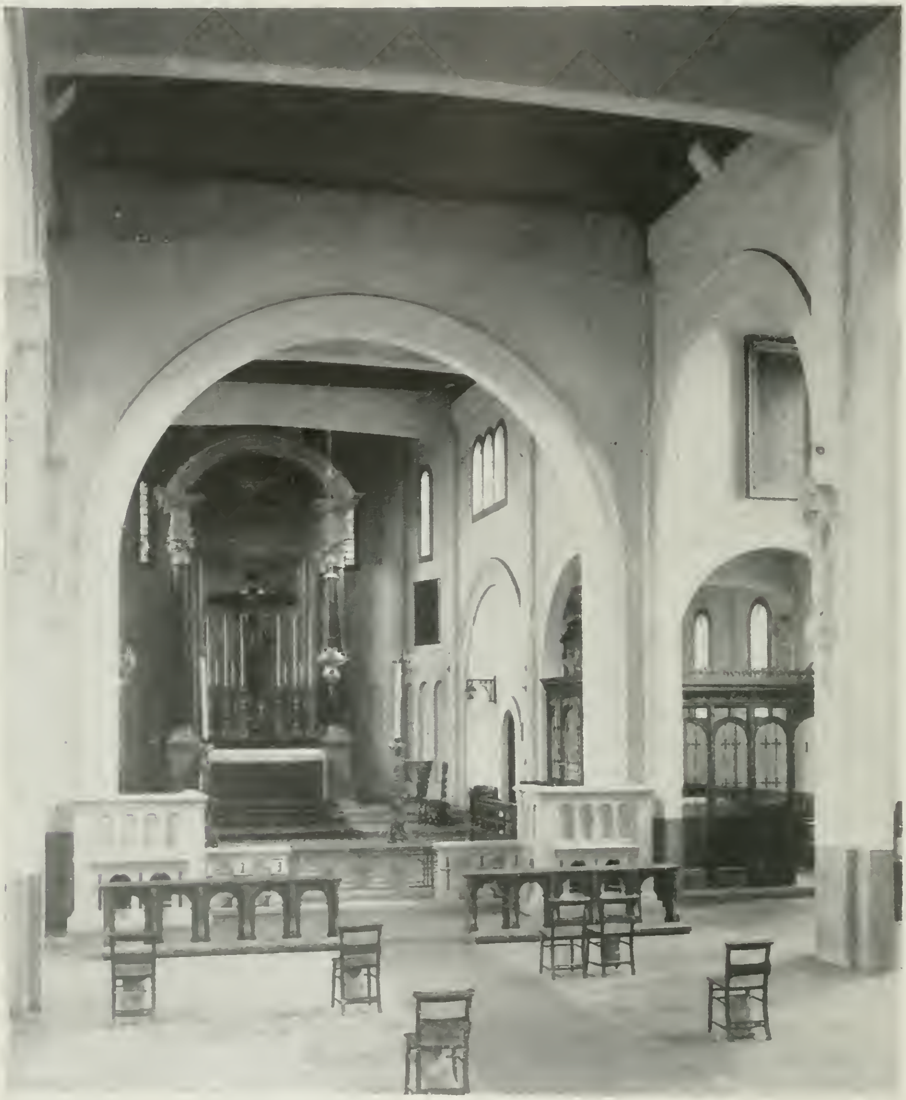


Fig. 7. View of Chancel.
Reinforced Concrete Church, Goldthorpe, Yorks.

chancel). This is also of concrete, partly left rough, partly smoothly trowelled and modelled, and with the supporting columns of black marble aggregates with gilded caps and bases.

The same material is also used for the Lady Chapel altar, and for the twelve statues and their supports and canopies, which are placed on the main piers, whilst the Stations of the Cross are modelled in plaster on the reinforced concrete walls.

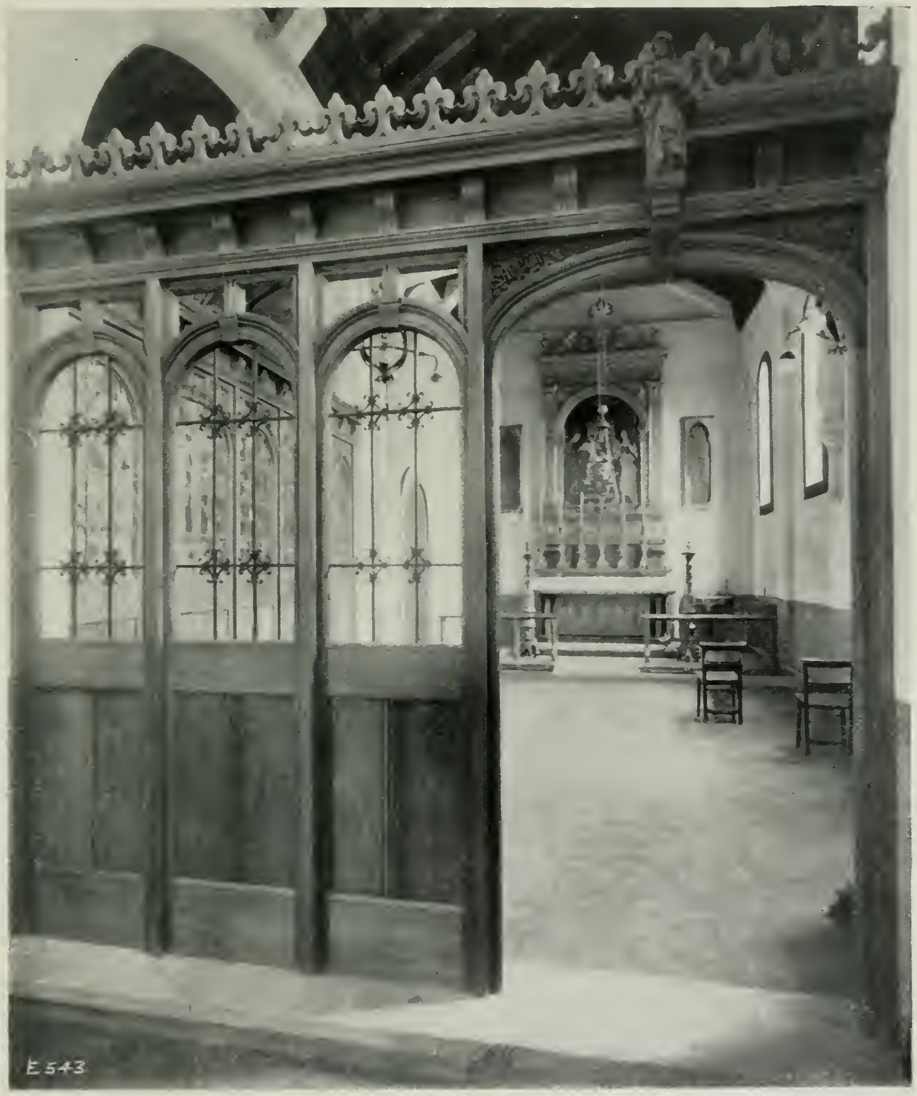


Fig. 8. Lady Chapel.
REINFORCED CONCRETE CHURCH, GOLDTHORPE, YORKS.

Connected with the church by an ambulatory is the clergy house. This building is also of reinforced concrete, and, as will be seen from the drawings

(*Figs.* 14 to 16), is designed to show the constructional lines of the building. It rests on a concrete beam raft, similar to that for the church, and is finished with a red tiled roof.

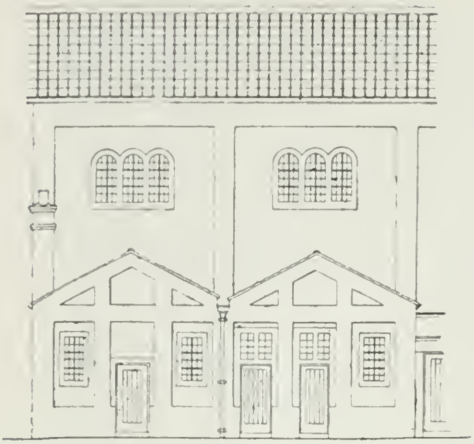


Fig 9. Elevation of Vestry Entrance.

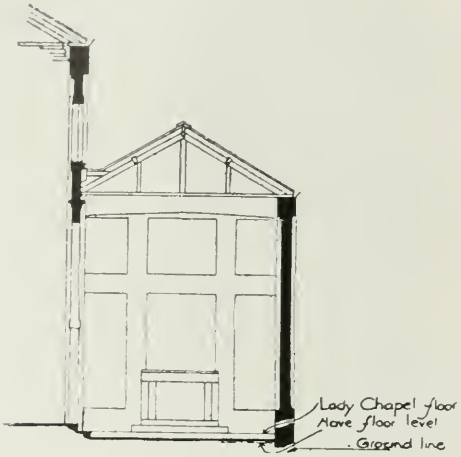


Fig 10. Section through Lady Chapel.

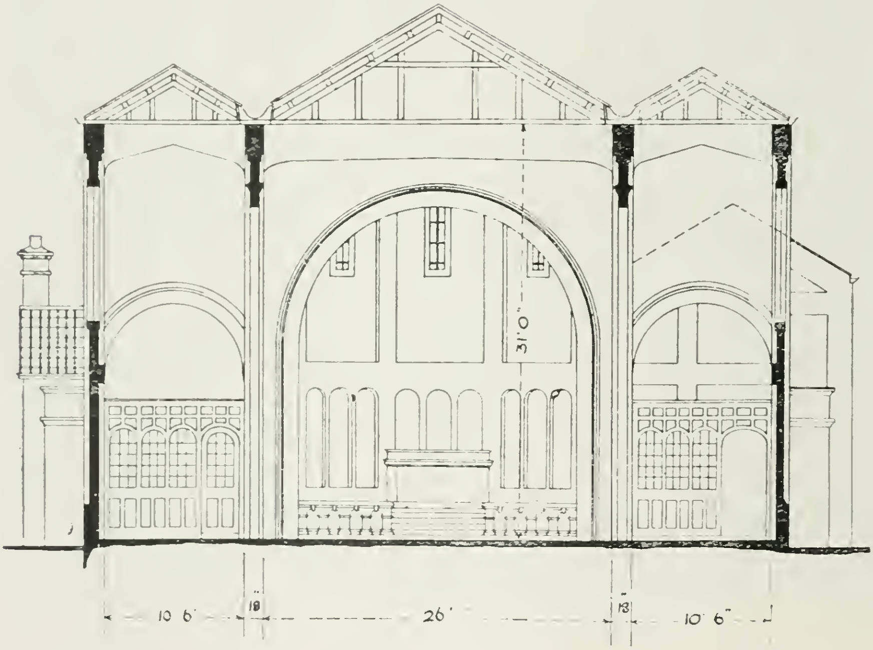
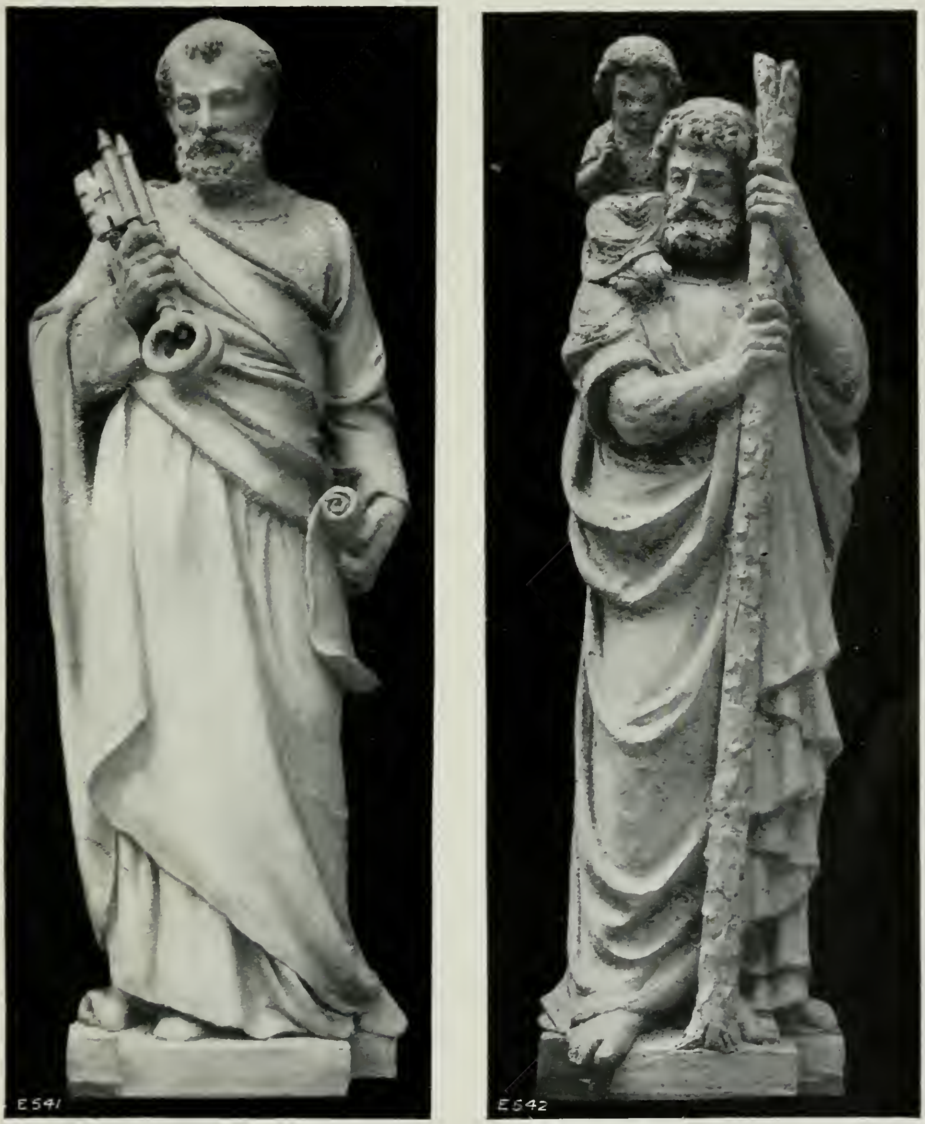


Fig. 11. Transverse Section.
REINFORCED CONCRETE CHURCH, GOLDTHORPE, YORKS.

It may be of interest to mention that the church raft contains about 8,700 cu. ft. of concrete and 18 tons of steel, that the superstructure of the church contains 17,500 cu. ft. of concrete and 30 tons of steel, whilst a further

1,050 cu. ft. of concrete and 5 tons of steel are used in the tie beams to the roof.

The architect for the work was Mr. A. Y. Nutt, of Slough (for many years in H.M. Office of Works), and the reinforced concrete contractors were Messrs.



St. Peter.

St. Christopher.

Fig. 12. Reinforced Concrete Statuary, Goldthorpe Church.

(Two of the figures on piers of nave—their position being shown on Fig. 7.)

Hodkin and Jones, of Sheffield. Messrs. Dennis Gill and Sons, of Doncaster, were the builders for the church, and Mr. J. C. Claxton, also of Doncaster, for

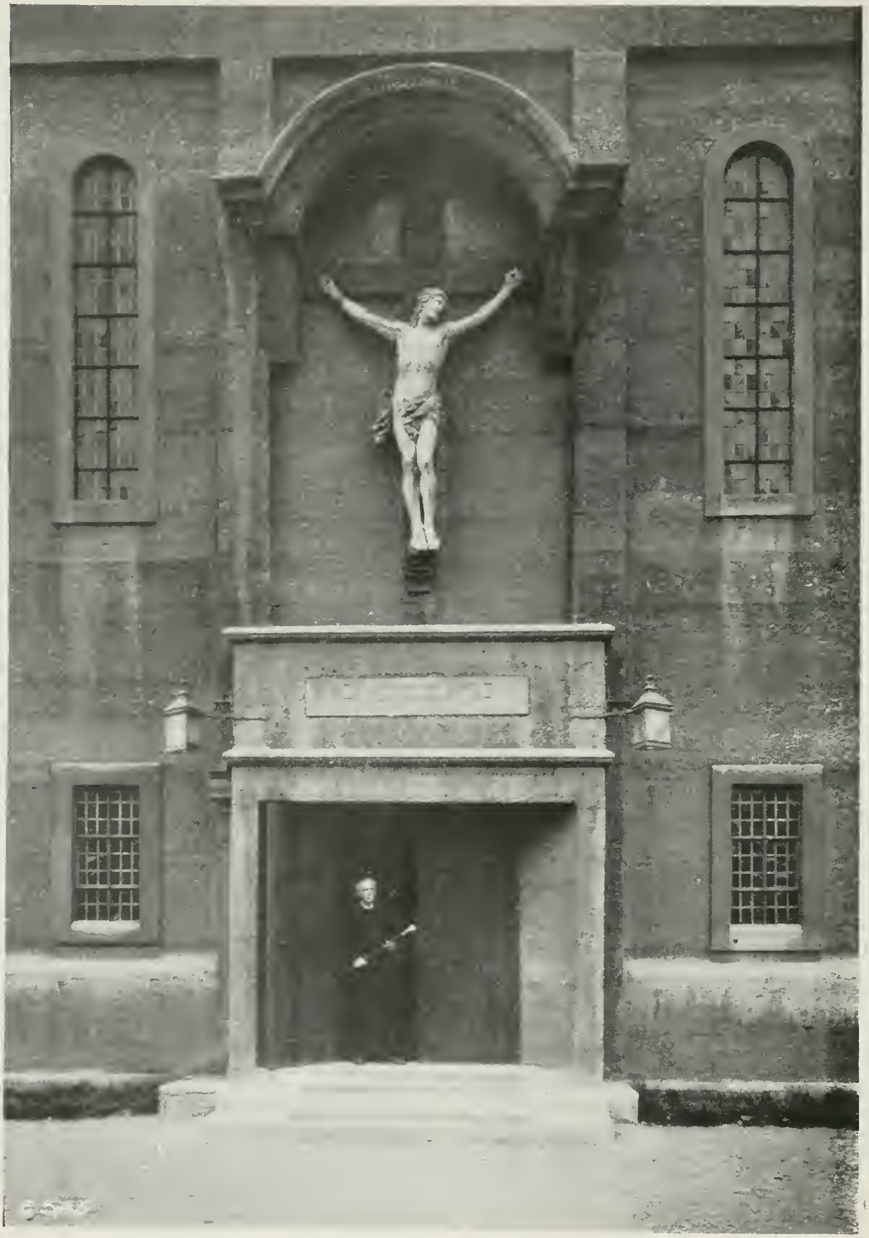


Fig. 13. Main Entrance to Church.
Reinforced Concrete Church and Clergy House, Goldthorpe, Yorks.

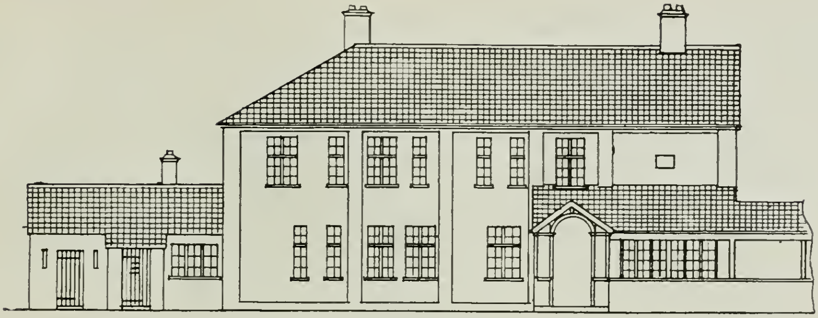


Fig. 14 Front Elevation.

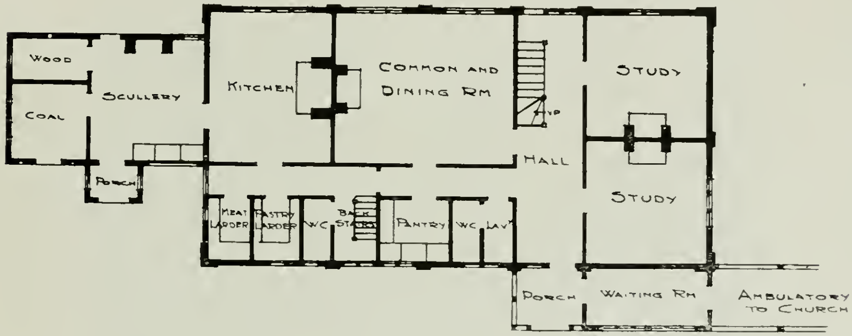


Fig. 15. Ground Floor Plan.

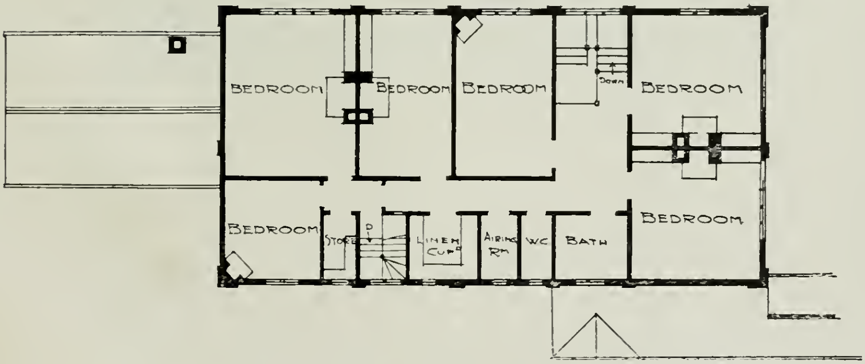


Fig. 16. First Floor Plan.

Reinforced Concrete Clergy House, Goldthorpe, Yorks.

the clergy house. The figure work is by Messrs. Boulton and Sons, of Cheltenham, and the Stations of the Cross and paintings over the lady chapel altar are by Mr. Bartlett, art worker, of Westminster.

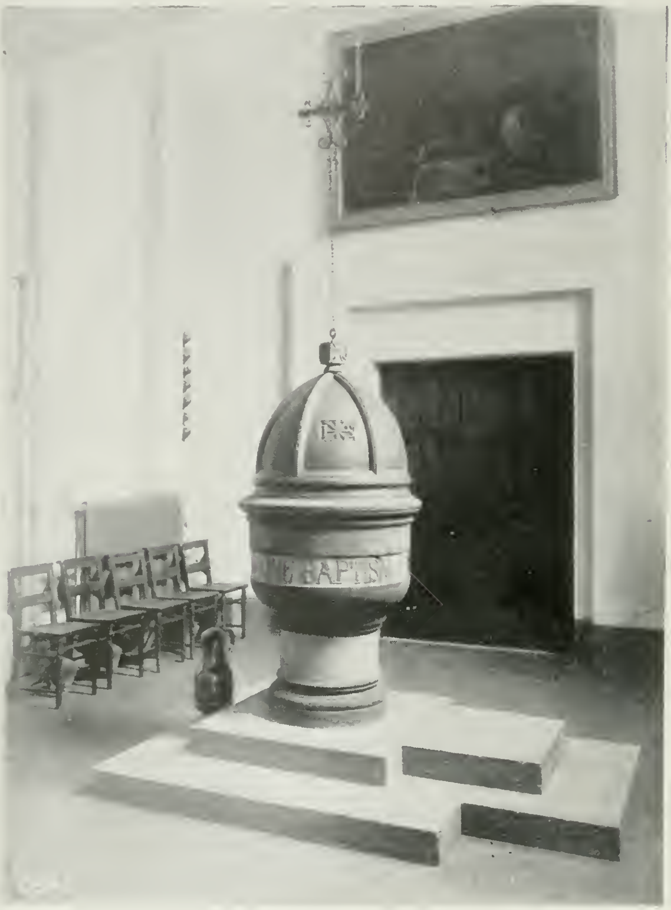
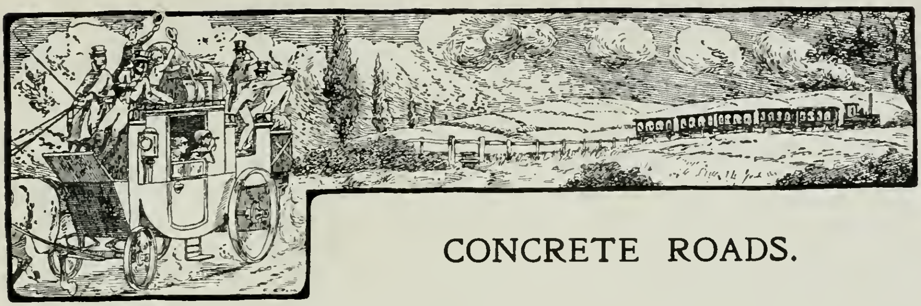


Fig. 17. Reinforced Concrete Font.
Reinforced Concrete Church at Goldthorpe, Yorks.



CONCRETE ROADS.

By H. PERCY BOULNOIS, M.Inst.C.E., etc.,
Member of the Advisory Committee of the Road Board.

Following upon this article by Mr. Boulnois we publish the results of some interesting experiments on road construction that have been made in Australia.—ED.

Does it not seem rather surprising that, whereas between 1910 and the end of 1915 nearly 52 million square yards of concrete roads were constructed in America and Canada, only a few thousand square yards of such roads have been laid down in this country? It cannot be that the American road engineers are "backing the wrong horse," for the Americans are known to be shrewd men of business, and their definition of an engineer is that of a man "who can do for one dollar what any fool can do for two." They are not likely to have wasted about 50 million dollars in an experiment, and from the various reports that are now being received of the cost and behaviour of their concrete roads, it is evident that such a form of construction has come to stay. In our country the efforts at concrete road building have been very few, and in some cases not very successful. Although at Chester Mr. Matthews Jones has constructed some excellent concrete roads, and at Exmouth Mr. Hutton has built a very fine example of reinforced concrete road on the new esplanade, and there are other sporadic examples of such construction, these roads are not carrying very heavy traffic, and are, consequently, not looked upon as types of road building which will stand heavy modern traffic. The only trial length of road constructed of concrete, which was "fathered" by the Road Board, was that in the county of Kent, near Gravesend, which, for various reasons (which are explainable), was in part not altogether a success. This partial failure, however, was not due to failure of concrete as a road material, but to various causes which were unfortunate. The weather was bad, the traffic could not be diverted, and was concentrated (on a width of about 10 ft.) upon the freshly laid concrete; and other minor causes conduced to spoil what might otherwise have been a good example of a concrete road. When the American specifications are compared with the specifications under which the Kent road trial section was constructed, it will be seen that, had the former specifications been followed, the result might, and probably would have been, very different. The chief points to which the American road engineers appear to attach importance may be summarised as follows:—

(1) That the concrete shall be "fat." That is, that the proportions shall be 1 of cement to 1 of sand and 2 of hard stone broken to a $1\frac{1}{2}$-in. gauge. In the Kent trial road the concrete was only 1 to 6; a portion, however, which was laid with a 2-in. bearing surface of 1 to 3, stands up as well as the day it was laid, which bears out the American principle of not making the concrete too weak. It may be mentioned,

however, that this road was laid in the early part of 1915, and that the traffic on it is about 1,000 tons a day. So far no repairs have been necessary on this portion of the road.

(2) The sand and other material must be well washed.

(3) The cement must comply with the standard specification.

(4) The water must be added in proper proportion, all the materials very carefully measured in their due proportions, and thoroughly mixed and incorporated together

(5) The natural foundation or sub-grade must be of even surface and be thoroughly wet before the concrete is placed thereon, but shall show no pools of water. The sub-grade is generally laid flat and not contoured to the finished face of the road. It is contended in America that if the concrete is thicker in the centre than the sides there is less liability to contraction or expansion. This practice has the disadvantage of weakening the haunches unless there are kerbs on each side of the carriageway.

(6) Considerable importance is attached to the finishing of the surface, which should be done with an iron-shod template and not by ordinary floating. It is contended that a more even face is thus produced, and any waves or hollow places are eliminated.

(7) It is essential that the natural foundation or sub-grade shall be thoroughly drained before the concrete is laid thereon, and be kept free of water by drainage.

There are many other details in the American specifications to ensure successful work, and it is common knowledge that unless considerable care is exercised in the construction of a concrete road there are liabilities of failure. Successful road making is, after all, very like cooking in the hands of an unskilful person the best materials will turn out unsavoury dishes, whereas in the hands of a real "chef" the results are completely successful.

With regard to cost: there was an excellent article in the November number of CONCRETE by Mr. Matthews Jones on the paper presented by Mr. Eugene W. Stern to the National Conference on Road Building, held in Chicago in February of this year, in which some calculations were made, showing the first cost of road construction with various materials and the cost of maintenance for twenty years, in which it proved conclusively that, when maintenance was taken into account, a concrete road was the cheapest in the end.

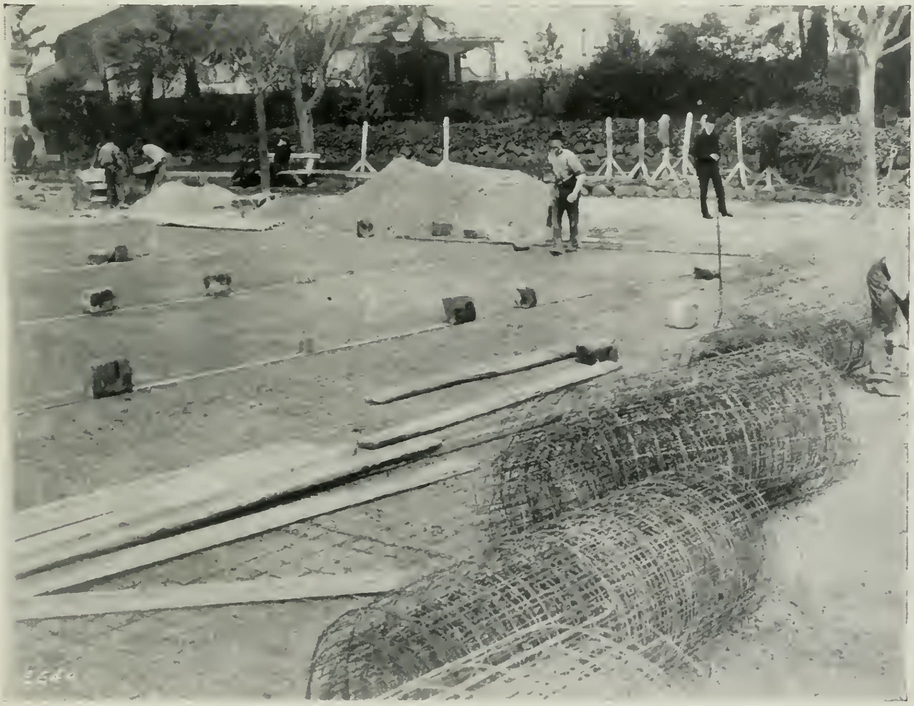
It is evident that a well-made concrete road has much to recommend it; but it is not, of course, contended that such construction is to supersede all other methods of road making. A number of considerations, local and others, must always be taken into account when selecting the materials and methods of construction of any road; but it does seem rather remarkable that concrete has not yet been given a fair trial in this country as a road material, whereas in America it is so largely used.

EXAMPLES OF CONCRETE ROAD CONSTRUCTION IN SYDNEY, MELBOURNE, & AUCKLAND.

CONTEMPORANEOUS with the introduction of the motor 'bus, the motor lorry, and other heavy-drawn, fast speeding, destructive road tractors, which, however, must not be blended with the ordinary motor car, has developed a need for the construction of roads sufficiently durable to withstand the heavy traffic and at the same time provide a smooth surface. In most of the capital cities of Australia, particularly Sydney and Melbourne, in which this class of traffic is fairly extensive, wood blocking has been carried out, and the difficulties of providing an almost perfect road have been overcome. But other municipalities, inter-urban, for instance, which are equally interested in motor 'bus traffic, are not able, wholly due to financial reasons, to wood block their roads, and, consequently, it is necessary to adopt a less expensive road. Tar macadam does not stand up against heavy motor traffic, though it is perfectly satisfactory for ordinary motor car services. Reinforced concrete roads, whether for heavy or light traffic, have been claimed to be a success in many places, and their efficiency is now being tried in some of the suburbs of Sydney and Melbourne. The reinforcement consists of a mesh of drawn steel wire, square, longitudinal and transverse, and triangular. The wires in the two former instances are electrically welded. The material, known as B. R. C. Fabric, is supplied in rolls of various sizes and of considerable length. The road is prepared in the usual manner for the reception of concrete. On the foundation is laid about two inches of concrete, the reinforcement being set in while the concrete is green. On top of the reinforcement is laid about four inches of concrete, which provides the road surface. In this method of road construction the weight is distributed by the steel reinforcement over the whole carrying surface of the area which constitutes the unit of construction.

ST. KILDA ROAD, MELBOURNE.

The Melbourne City Council is employing steel square mesh reinforcement on the west side of St. Kilda Road, between Princes Bridge and Nolan Street. In this instance the road comprises a portion of a filled up area, which in the past has presented some difficulties owing to settlement. A cross section shows 2 in. of concrete mesh reinforcement, 4 in. of concrete, on which wood blocks 5 in. high are laid. On the east side a plain concrete bed, 8 in. deep, also to carry wood blocks, is being constructed in order to test its efficiency with that of the reinforced section.



Western Motor Track, St. Kilda Road, Melbourne.
(Reinforced with B.R.C. Fabric.)

EXPERIMENTS WITH CONCRETE ROADS IN AUSTRALIA AND NEW ZEALAND.

An extended, and what may, so far, be called a satisfactory, test has been made by the South Melbourne City Council on the west side of St. Kilda Road on a section within the council's jurisdiction. It was carried out under the supervision of Mr. A. E. Aughtie, M.Inst.C.E., City Surveyor. Five different, but conjoint, sections of the road were laid with steel mesh—longitudinal and transverse and triangular—reinforcement supplied by two different makers, and with plain concrete, in order that a comparative test might be made of their relative values. In two instances the duration of time covers a period of two years, two others extend over a year, while one section was laid in March last. In March, 1914, one chain of road was experimented upon, 33 ft. being laid with plain concrete and 33 ft. with concrete and longitudinal and transverse steel mesh reinforcement. In June, 1915, 2½ chains of plain concrete road was put down; at the same time half a chain of concrete road with triangular mesh reinforcement was laid. In March, 1916, half a chain of concrete road with longitudinal and transverse mesh reinforcement was constructed.

The reinforcement in the several instances mentioned was laid in concrete 6 in. thick, while the plain concrete road was 6-8 in. The concrete mixture for the various tests comprised four parts of blue stone screenings, two parts of sand, and one of cement. The width of the road so treated is 24 ft., with 3 ft. of channelling on either side. The surface of the various sections was tar painted and sanded, the same as is done with wood block roads. The test, said Mr. Aughtie, had conclusively shown that there had been absolutely no wear on the surface, and to all appearances it was as sound as the day on which it had been laid. A number of transverse cracks, however, had appeared in the plain concrete road and at the junction of the reinforced road, but very few had shown themselves in the latter. Taking the reinforced sections as a whole, the cracks were of a very minor nature and gave evidence of durability.

The likelihood of cracks at the junction of the two type sections referred to was anticipated by Mr. Aughtie, who explained that the American practice regarding expansion joints did not clearly demonstrate their proper positions; in fact, the information supplied by American authorities varied very widely as to the distances which expansion joints should be placed. Again, the American practice was wholly confined to plain concrete roads, and there was no indication given in the reports available as to the climatic and traffic conditions to which roads were subjected. In making the experiments the engineer further explained he was anxious to determine the difference between the reinforced concrete road and the plain concrete road laid and trafficked upon under exactly similar conditions. As previously stated, there has been no wear on either road. In order, however, that the results of the experiments should be conclusive and to further test the value of reinforcement he had asked the council's permission to construct an additional five chains of road.

The cost of constructing the road with reinforcement was 8s. per square yard in 1914, and 9s. 6d. in 1915, the increase in the latter year being chiefly for the steel reinforcement, prices having advanced, and the heavier gauge being used. It must be mentioned that the road is reserved wholly for motor 'bus and motor car traffic. The South Melbourne Council has a length of about two miles to construct and maintain. To lay this section with wood blocks the same as is being done by the Melbourne City Council on its side of the road would cost about £28,000, so Mr. Aughtie adds if the efficiency of the reinforced concrete road can be thoroughly demonstrated, and at the cost of about 9s. per square yard, the capital expenditure will be less than half that required for a wood block road. The further experiments will be watched with interest, and should they prove successful, concrete roads should be extensively adopted.

The financial consideration involved in the project of wood blocking is an important one with the South Melbourne Council. Nearly all traffic on the council's side of the road proceeds to Melbourne from the southern suburbs, and the South Melbourne Council considers that the heavy expenditure necessary for wood blocking is not justified. Further, before the advent of the motor 'bus the tar macadam road answered all requirements, and was maintained in perfect condition, even with ordinary vehicular traffic. As an evidence of the approximate amount of motor and vehicular traffic on the road may be given particulars of a count taken for twenty-four hours between the hours of seven a.m. on March 7th, 1913, and seven a.m. on March 8th, 1913. Of course, the traffic has increased considerably during the past three years, and a line of motor 'buses from Melbourne to St. Kilda and return should be added in addition to increased motor traffic. The count was as follows:—

TRAFFIC INTO MELBOURNE.

Time.	Motor Car.	Motor Wagon.	Motor Bike.	Bicycle.	Heavy Wagons and Drays.	Light Vehicles.
7 to 1 ..	369	22	104	544	170	379
1 to 7 ..	416	16	61	228	226	434
7 to 12 ..	230	7	30	91	17	135
12 to 7 ..	76	3	7	77	360	174
	1,091	48	202	940	773	1,122

TRAFFIC FROM MELBOURNE.

Time.	Motor Car.	Motor Wagon.	Motor Bike.	Bicycle.	Heavy Wagons and Drays.	Light Vehicles.
7 to 1 ..	192	14	33	206	199	362
1 to 7 ..	513	11	126	533	196	492
7 to 12 ..	236	5	41	118	18	152
12 to 7 ..	72	—	7	63	5	119
	1,043	30	207	920	418	1,125

NEW SOUTH HEAD ROAD, SYDNEY.

At the present time the Woollahra Council, Sydney, are experimenting with a section of the New South Head Road, near Mona Road, Darling Point. There is a foundation of a depth of 6 in., consisting of concrete made in the following proportions:—8 cu. ft. of 1½-in. blue metal, 8 ft. of ¾-in. metal, or "shivers," 10 ft. of blue metal screenings, and 4 ft. of cement. Above this layer of concrete is laid the reinforcement. Above this is the wearing course, which consists of a rich concrete mixture of two parts of blue metal screenings to one of cement. The length of road being constructed is 160 ft., with expansion joints 20 ft. apart.

AUCKLAND, N.Z.

Recently the city of Auckland, N.Z., had one of the important thoroughfares—Little Queen Street—constructed of concrete. The street is described by Mr. James Tyler, A.N.Z.Soc.C.E., as being 428 ft. in length and 66 ft. wide; the roadway, or concrete pavement, is 46 ft. wide. The road previously was formed of ordinary macadam on a boulder formation, so that after the scarifying and removal of the metal and some of the boulders a compact road bed was obtained. Six inches of 7 to 1 cement concrete was placed as a foundation course; on the foundation a 2-in. 3 to 1 layer of surfacing course quickly followed, special care being taken to lay the surface course before the bed was set. The foundation was finished with a shovel, but the surface was carefully screeded and worked up with trowels. The surface (when hard enough) was lightly broomed; this removed the somewhat polished face and provided a less slippery pavement for horse traffic. Each day the work was covered with damp bags, the bags being kept in this condition for about ten days. No traffic was allowed on the pavement until three weeks after completion.

The aggregate of the foundation consisted of 1 part cement, 5 parts beach shingle, including sand, and two parts 2 in. to $2\frac{1}{2}$ in. metal, and the top surface of 1 part cement, 2·25 parts of beach shingle and sand, and ·75 part of $\frac{5}{8}$ in. metal chips. The longitudinal gradient does not exceed 3 per cent., and the cross-fall or crown varies from 1 in 36 to 1 in 22, the latter being necessary because of the grade of the intersecting street. No expansion joints were provided, the method of concreting being in 14 ft. transverse bays. Each bay joint was coated with soft soap, thus a joint was made to provide for contraction, and will prevent other cracks occurring.

The Auckland City Council have since decided to pave Durham Street with concrete.

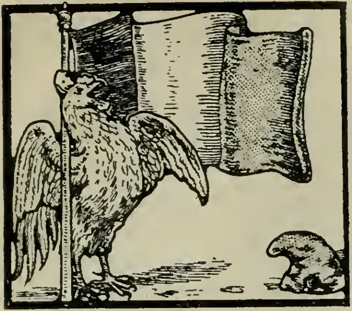
Maintenance Cost of Main Roads in Kent.—According to the report of the Kent County Surveyor, published in *The Surveyor and Municipal and County Engineer*, on November 17th, the expenditure for maintenance, etc., of the $600\frac{1}{4}$ miles of main roads in that county for one year, ending March, 1916, was £104,643, which equals £174·2 per mile.

Concrete Roads in Western Washington.—These are maintained at a cost of less than $40 (£8) per mile per annum.

The Experimental Concrete Road near Gravesend.—That section of it which was topped with a proportion of 3 to 1 concrete on a 4 in. bed of 6 to 1, and which has had traffic of about a thousand tons a day over it for more than a year and a half, still remains in perfect condition, and that part of it without even tar-coating has not had a penny spent on it since it was opened.

Motor Omnibuses on Country Roads.— Recently a case came before Mr. Justice Sankey, in the Court of King's Bench, in which the Abingdon Rural District Council were awarded £350 as expenses incurred for repairs to certain roads brought about by what was termed "extraordinary traffic" on the part of motor omnibuses belonging to The City of Oxford Electric Tramways, Ltd. The latter had to pay the sum mentioned. The moral of this is that motor omnibus companies and others using country roads should strongly advocate for immediate steps to be taken to see that good sound main roads are laid down.

A Model Specification for Concrete Roads.—We shall publish in our next issue a model specification for the construction of concrete roads. This, however, must be regarded as being purely in the light of a suggestion.



THE CALCULATION OF REINFORCED CONCRETE STRUCTURES. — RAPID METHODS APPLICABLE TO BEAMS.

By N. DE TEDESCO.
Civil Engineer, Ecole Centrale, Paris.

BASES OF CALCULATION.

THE bases of calculation of members subjected to bending are as follows:

The transverse sections of the members must be divided into four categories:

1. The part A of the concrete in compression, that is, the part of the section considered which is above the neutral axis for positive bending moments, and below it for negative moments.
2. The longitudinal reinforcement A_c situated in the part in compression A; the total cross-section A_c must be multiplied by m, m being the ratio of the coefficients of elasticity of steel and concrete, or $m = \frac{E_c}{E_s}$.
3. The longitudinal reinforcement A_t situated in the part in tension; the total cross-section must be multiplied by m, giving mA_t.
4. The concrete in tension, that is, the part situated below the neutral axis for positive bending moments, and above it for negative moments. This part must be considered as non-existent for the calculation of the working stress, and is only taken into account in calculating the deformations.

Lastly, there exists another element, the transverse reinforcement or stirrups, which only enter into consideration for the calculation of the shearing stress.

These conditions being observed, reinforced concrete beams may be treated as homogeneous, according to the same rules as beams of metal or wood.

In computing a section of height d (effective depth of the beam, or depth of A_t below top of surface) the position of the neutral axis is first found, or the value of n (depth of neutral axis from the extreme compressed edge), then the sum I of the moments of inertia of the parts 1, 2, and 3 in reference to the neutral axis. We then have for the maximum working stress of concrete in compression $c = \frac{Bn}{I}$, where B is the bending moment of the external stress, and for that of steel in tension, $t = \frac{B(d-n)}{I} \times m$. The presence of the coefficient m constitutes the only difference between the resistance of homogeneous material and that of heterogeneous material treated in the above manner.

In other words, given the section of a member subjected to bending, the position of the neutral axis is determined by the expression that the sum of the products of the elements of area in compression by the distances of their centres of gravity from that line is equal to the sum of the products of the elements of area in tension by the distance of their centres of gravity from the neutral axis. On solving the equation, therefore,

$$bn \times \frac{n}{2} + m\,A_c\left(n - \frac{n}{3}\right) - m\,A_t\,(d-n) = 0$$

and consequently

$$I = \frac{bn^3}{12} + bn \times \frac{n^2}{4} + m\,A_c\left(n - \frac{n}{3}\right)^2 + m\,A_t\,(d-n)^2$$

If the working loads

$$c = \frac{Bn}{I} \qquad t = \frac{B\,(d-n)}{I} \times m$$

do not exceed the limits respectively fixed for concrete in compression and steel in tension, and are suitably near to one another, it is because the dimensions of the section considered have been judiciously chosen, as well as the sectional area of the reinforcement, but, if this should not be the case, the first design must be modified by successive and tedious trials. It is therefore useful to have simple and rapid methods of avoiding such trials, and such is the object of the present contribution.

These methods will be tested by numerical examples, applying the procedure which has been explained in a general manner, and which will become clearer as it is further applied. The engineer who has followed these calculations, convinced of the correctness of the coefficients proposed, will not need to verify them by the general method, unless required to do so by the authorities. It may be said at once that these coefficients are not empirical, but entirely rational, and result from mathematical processes which are not developed here on account of space.

Coefficients relating to the Design of Slabs and Rectangular Beams.

The principal coefficient, which is the base of all the others, will be designated by α. It gives immediately the position of the neutral axis for given values of c, t, or m, that is, $n = \alpha d$.

$$(1) \quad \alpha = \frac{m\,c}{m\,c + t}$$

For the most usual case, $m = 15$; $c = 600$ (1 : 2 : 4 concrete giving a strength of 1,800 lb. after 28 days); $t = 16{,}000$ (steel of 60,000 lb. resistance);

$$\alpha = \frac{15 \times 600}{15 \times 600 + 16000} = 0{\cdot}36$$

for which $n = 0{\cdot}36\,d$.

For any other case it is only necessary to replace m, c, and t by their respective limits in equation (1), and the other coefficients derived from α will vary accordingly.

The first coefficient derived from α is β, which gives directly the moment of resistance, B, in inch-pounds in a slab of 1 ft. breadth and effective depth, d; $B = \beta d^2$.

$$\beta = 2c\,\alpha\,(3 - \alpha)$$

In the actual conditions mentioned above

$$\beta = 2 \times 600 \times 0{\cdot}36\,(3 - 0{\cdot}36)$$

$$\beta = 1{,}140$$

therefore $B = 1{,}140\,d^2$.

$$d = \sqrt{\frac{B}{1140}}$$

B is expressed in inch lbs. per foot breadth and d in inches.

The second derived coefficient is γ, which gives directly the section of steel to be provided per foot breadth in square inches. $A_t = \gamma d$.

$$\gamma = \frac{6\,c\,\alpha}{t}$$

In the above conditions

$$\gamma=\frac{6\times600\times0{\cdot}36}{16000}=0{\cdot}081$$

therefore $A_t=0{\cdot}081\,d$.

A_t is expressed in sq. in., and refers to 1 ft. breadth.

This being given, we may immediately determine the depth of a given slab of any span, subjected to a given total load.

Numerical Example (1).

To find the depth of a slab 6 ft. in length between supports that will sustain a uniform load of 2 cwt. per sq. ft., including its own weight.

$$B=\frac{2\times112\times6^2\times12}{10}=9676{\cdot}8\text{ in.-lb.}$$

$$d=\sqrt{\frac{9676{\cdot}8}{1140}}=2{\cdot}907$$

$$A_t=2{\cdot}907\times0{\cdot}081=0{\cdot}2355$$

Selecting suitable reinforcement (rods $\frac{3}{8}$ in. diameter, area 0·11) the distance from centre to centre is

$$\frac{12\times0{\cdot}11}{0{\cdot}2355}=5{\cdot}61\text{ in.}$$

Verification 1 (*Fig.* 1).

To find n. $\qquad d=2{\cdot}907,\ m\,A_t=15\times0{\cdot}2355$

$$=3{\cdot}532$$

$$\frac{12\,n^2}{2}-3{\cdot}532\,(2{\cdot}907-n)=0$$

$$n=1{\cdot}047$$

To verify the coefficient a

$$n=0{\cdot}36\times2{\cdot}907=1{\cdot}04652$$

We have, for $2{\cdot}907-n$, $2{\cdot}907-1{\cdot}047=1{\cdot}86$

$$I=\frac{12\times\overline{1{\cdot}047}^3}{3}+3{\cdot}532\times\overline{1{\cdot}86}^2$$

$$I=4{\cdot}590+12{\cdot}220=16{\cdot}810$$

$$\frac{B}{I}=\frac{9676{\cdot}8}{16{\cdot}81}=575{\cdot}66$$

$$c=\frac{Bn}{I}=\frac{9676{\cdot}8\times1{\cdot}047}{16{\cdot}81}=575{\cdot}66\times1{\cdot}047$$

$c=602{\cdot}7$ instead of 600, on account of decimals omitted.

$$t=\frac{B}{I}15\times(2{\cdot}907-1{\cdot}047)=575{\cdot}66\times15\times1{\cdot}86$$

$t=16061$ instead of 16000, on account of decimals neglected.

The verification may be continued as follows:—

a being equal to 0·36, the lever arm is

$$a=\left(1-\frac{0{\cdot}36}{3}\right)d=0{\cdot}88\ d.$$

$$a=0{\cdot}88\times2{\cdot}907=2{\cdot}558$$

The resultant traction, equal to the resultant compression, then has the value

$$T=\frac{B}{a}=\frac{9676{\cdot}80}{2\ 558}=3783\text{ lb.}$$

therefcre

$$t=\frac{T}{At}=\frac{3783}{0{\cdot}2355}=16064$$

$$c=\frac{3783}{12\times1{\cdot}047}\times2=602$$

REMARKS.

I. It is usual to assume for the expression for the moment of external loads, $B=\frac{wl^2}{10}$, for slabs constructed in a continuous manner on parallel beams, or on two walls the masonry of which is continued above the slabs. If the slabs rest freely on two supports, the value $B=\frac{wl^2}{8}$, and if, on the contrary, the fixing is complete, $B=\frac{wl^2}{12}$

II. To pass from d (effective depth) to d_s (total depth) it is usual to add ¾ in., more or less, so as to give a convenient figure. In the example given above $d_s=2{\cdot}907+0{\cdot}843=3\tfrac{3}{4}$ in.

III. The rods are turned upwards near the supports towards the top surface for negative moments (*Fig.* 2) at a distance of ¾ in. from the latter, whatever the degree of fixing.

IV. It is advisable to provide reinforcement in the form of rods perpendicular to the principal rods and above them (for positive moments), usually ¼ in. diam., distance from centre to centre 1 foot.

V. In the example given above the total load was intentionally taken to include own weight. But evidently the weight of the slab is not known at once beforehand, so that repeated trials are necessary. To avoid these trials, a table of moments of resistance and loads which slabs of different thicknesses are capable of carrying may be drawn up. The method of utilising such a table, so as to secure the maximum economy, will be indicated later.

Table for Calculation. Table I has been constructed in the following manner:—

Take $d_s=5$; $d=4{\cdot}25$

$M=\overline{4{\cdot}25}^2\times1140=20591$ in.-lb.

Own weight 13 lb. per sq. ft., $5\times13=65$

Total load $4\times112+65=513$

$$B=\frac{513\ 1^2}{10}\times12=20591$$

$$1=\sqrt{\frac{20591\times10}{12\times513}}=5{\cdot}78$$

5·75 may be taken for safety.

$A_t=4{\cdot}25\times0{\cdot}081=0{\cdot}3441$

0·350 may be taken for safety.

Method of using Table I.

Required the thickness d_s and the reinforcement A_t necessary for a slab of 6 ft. span, carrying a load of 2 cwt. per sq. ft., excluding own weight. The column *h* gives for span 6 ft.:—

$d_s=4$ in., $A_t=0{\cdot}265$ sq. in. per ft.

For round rods ⅜ in. diam., section 0·11 sq. in. at a distance from centre to centre

$$\frac{0{\cdot}11\times12}{0{\cdot}265}=5 \text{ in.}$$

TABLE I.

MAXIMUM SPANS OF SLABS SUPPORTING THE FOLLOWING LOADS (OWN WEIGHT EXCLUDED)

$m=19$; $c=600$; $t=16{,}000$; DEGREE OF FIXING: $B=\frac{wl^2}{10}$

ds in.	*d* in.	*M* in. lb.	*At* sq. in.	Own Weight. lb. per ft.	Cwt.					
					½	1	2	3	4	5
					ft.	ft.	ft.	ft.	ft.	ft.
2·0	1·25	1·761	0·110	26·0	4·2	3·2	2·3	2·0	1·7	1·5
2·5	1·75	3·491	0·145	32·5	5·7	4·4	3·3	2·8	2·4	2·2
3·0	2·25	5·771	0·185	39·0	7·1	5·6	4·2	3·5	3·1	2·8
3·5	2·75	8·621	0·225	45·5	8·4	6·7	5·1	4·3	3·8	3·4
4·0	3·25	12·041	0·265	52·0	9·6	7·8	6·0	5·0	4·4	4·0
4·5	3·75	16·031	0·310	58·5	10·7	8·8	6·8	5·8	5·1	4·6
5·0	4·25	20·591	0·350	65·0	11·8	9·8	7·7	6·5	5·7	5·2
5·5	4·75	25,721	0·390	71·5	12·9	10·7	8·5	7·2	6·4	5·8
6·0	5·25	31·421	0·430	78·0	13·9	11·7	9·3	7·9	7·0	6·4
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*

The value 5·67 in. had been found for a load of 2 cwt., including own weight.

But it is only rarely that the agreement will be so close, and then an interesting method is resorted to, Table I. only applying in special conditions, which have here been termed the most usual case. That is, should a different concrete be employed, for which the values of c and t are either greater or less than 600 and 16,000 lb. per sq. in. respectively, and if the degree of fixing should differ from $B=\frac{wl^2}{10}$, the figures of this table are no longer suitable for giving the thickness to be chosen. A value of d_s, which is certainly greater than is necessary, is now taken, which has no disadvantage except that of giving a larger mass of concrete than is necessary, but this is largely compensated by the smaller quantity of reinforcement, the section of the reinforcement being inversely proportional to the lever arm a, and approximately to the value of d, but with a small additional margin of safety.

Example (2).

Design of slab, 5 ft. span, 3·5 cwt. load, excluding own weight ($m=15$, $c=600$, $t=16{,}000$.)

Table I. shows in column i, 5 ft. span, $d_s=4$ in.

Take $d_s=5$; $d=4{\cdot}25$; own weight $=65$ lb.

Total load $=3{\cdot}5\times112+65=457$ lb.

$$B=\frac{457\times5^2}{10}\times12=13{,}710 \text{ in.-lb.}$$

(For a different degree of fixing wl^2 would be divided by 8 or 12, as the case may be)

$$d=\sqrt{\frac{13710}{1140}}=\sqrt{12{\cdot}03}=3{\cdot}47 \text{ in.}$$

(For different values of c and t we should calculate the values of

$$\alpha=\frac{mc}{mc+t};\ \beta=2c\alpha\,(3-\alpha);\ \gamma=\frac{6c\alpha}{t};\ \text{from which}$$

$$d=\sqrt{\frac{B}{\beta}};\ A_t=\gamma d.)$$

we then have $A_t=0{\cdot}081\times3{\cdot}47=0{\cdot}2776$, but as $d=4{\cdot}25$, we make

$$A_t=0{\cdot}081\times3{\cdot}47\times\frac{3{\cdot}47}{4{\cdot}25}=0{\cdot}230$$

or more simply, noting that $3{\cdot}47\times3{\cdot}47=12{\cdot}03$ (*see above*):

$$A_t=\frac{B}{1140\times4{\cdot}25}\times0{\cdot}081=\frac{13710}{1140\times4{\cdot}25}\times0{\cdot}081$$
$$=0{\cdot}230$$

(which avoids the extraction of a square root).

The volume of concrete has therefore been increased a little, but in return the steel has been reduced from 0·278 to 0·230 sq. in.

Verification (2).

$$B=13{,}710\,;\ d=4{\cdot}25\,;\ m=15\,;\ A_t=0{\cdot}230\,;$$

$$mA_t=3{\cdot}45\,;\ \frac{12n^2}{2}-3{\cdot}45\,(4{\cdot}25+n)=0$$

$$n=1{\cdot}28\,;\ d-n=3{\cdot}45-1{\cdot}28=2{\cdot}97$$

(The normal slab would have given $0{\cdot}36\times4{\cdot}25=1{\cdot}53$; the concrete being in excess, the neutral axis is raised)

$$\mathrm{I}=\frac{12}{3}\times\overline{1{\cdot}28}^3+3{\cdot}45\times\overline{2{\cdot}97}^2$$

$$\mathrm{I}=8{\cdot}388+30{\cdot}429=38{\cdot}817$$

$$\frac{B}{\mathrm{I}}=\frac{13710}{38{\cdot}817}=353{\cdot}4$$

$$C=\frac{Bn}{\mathrm{I}}=353{\cdot}4\times1{\cdot}28=452{\cdot}4<600$$

(which shows that the concrete is in excess)

$$t=\frac{B}{I}\times(d-n)\times15=353{\cdot}4\times2{\cdot}97\times15=15{,}744<16{,}000$$

(which confirms the proportions, the rule being slightly unfavourable).

CALCULATION OF STEEL IN COMPRESSION.

We have seen that we may obtain an effective thickness greater than the normal, that is, $d>\sqrt{\frac{B}{\beta}}$, and that it is then permissible to diminish the area of the reinforcement in tension according to a simple law. But if, on the contrary, we arbitrarily take $d<\sqrt{\frac{B}{\beta}}$, the concrete, instead of being under a less load than 600 lb., has a greater. It is therefore necessary to provide a section of steel, A_c, in the zone of compression n, in order to bring c down to 600 lb. This solution is not economical, seeing that for equal resistance steel is more costly than concrete, and the more so in this case, that its working load cannot exceed mc, or, in the usual case, $15\times600=9{,}000$, instead of 16,000, the figure assumed for tension. Reinforcing rods in compression are therefore rarely resorted to, and mostly for beams of rectangular form, a special case of slabs, of great thickness in proportion to their breadth, b, instead of a small thickness in proportion to their breadth, as in the cases considered hitherto, where only a fraction equal to one foot has been taken, whence the factor 12 which will have been observed.

This problem is somewhat complex, but it may be simplified on condition of placing the compressed bars in the axis of compression situated at the distance of $f=\frac{n}{3}$ from the compressed surface, a condition which may be realised in general, at least sufficiently nearly for slabs, so as not to alter greatly the results of the calculation.

In that case we may write that the resultant of tension is equal to the resultant of compression, increased by the resistance provided by the steel in compression, that is :

$$A_t\times t=12\times\frac{c}{2}n+A_c\times\frac{2}{3}mc$$

$\frac{2}{3}\,mc$ being taken because it is the compressive load in the concrete in the upper third of the zone in compression n and the coefficient m in order to express the increase due to the steel.

From this equation we have

$$A_c = \frac{A_t \times t - 6cn}{\frac{2}{3}\,mc} \qquad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

A_c may also be determined by means of the identical equation

$$A_c = \frac{B - \beta d^2}{\frac{2}{9}\,mc\,(3-\alpha)\,d}$$

which appears more complicated, but is really simpler, bearing in mind that the factor $\frac{2}{9}\,mc\,(3-\alpha) = \delta$ may be calculated once for all. In fact, for the most usual case $\delta = \frac{2}{9} \times 15 \times 600\,(3 - 0{\cdot}36) = 5{,}280$.

We then write $A_c = \dfrac{B - \beta d^2}{\delta\, d}$ generally, and

$$A_c = \frac{B - 1140\,d^2}{5280\,d} \qquad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

in the most usual case, this expression being no other than the moment of the external load and of the effective depth d.

(If it be wished to take account of this curious transformation, all the terms of expression (1) are multiplied by the resisting lever arm, $a = d\;(1 - \frac{\alpha}{3})$ or d $(1 - \frac{0{\cdot}36}{3}) = 0{\cdot}88\,d$ in the most usual case, and the factor $2c\alpha\,(3-\alpha)$ is replaced by β the value previously found.)

Noticing that n has again the value $\alpha\,d$, since it is arranged that the maximum compression in the concrete is equal to the value c which has been fixed, and so that the tension t shall also be that fixed upon, the value of n is at once known, and consequently that of $\frac{n}{3}$, and that of A_t is expressed by

$$A_t = \frac{B}{at} = \frac{3B}{(3-\alpha)\,dt}$$

or in the most usual case

$$A_t = \frac{B}{0{\cdot}88\,dt} = \frac{B}{14080\,d} \qquad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

The problem is therefore solved directly without the method of trial by the simple equations (2) and (3).

Example (3).

It is required to give the thickness of 4 in. to a slab loaded with 4 cwt. (exclusive of own weight) over a span of 5 ft., to find what reinforcement A_c and A_t must be provided:

$(d = 4 - 0{\cdot}75 = 3{\cdot}25$ in.)

Own weight: $4 \times 13 = 52$ lb.

Load: $4 \times 112 = 448$,,

Total load $= 500$,,

$$B = \frac{500 \times 5^2 \times 12}{10} = 15000 \text{ in.-lb.}$$

$$\text{from which } A_t = \frac{15000}{14080 \times 3{\cdot}25} = 0{\cdot}328 \text{ sq. in.}$$

$$A_c = \frac{15000 - 1140 \times \overline{3{\cdot}25}^{\,2}}{5280 \times 3{\cdot}25} = 0{\cdot}173 \text{ sq. in.}$$

Verification (3).

Take $b=12$; $d=3{\cdot}25$ *f.* the distance of the axis of compression of the concrete from the compressed surface,

$$=\frac{n}{3}=\frac{0{\cdot}36\times3{\cdot}25}{3}=0{\cdot}39$$

$$mA_c=15\times0{\cdot}173=2{\cdot}6\,;\quad mA_t=15\times0{\cdot}328=4{\cdot}92$$

As has been remarked above, the value of n is known, being equal to $ad=0{\cdot}36\times3{\cdot}25=1{\cdot}17$.

The moment of inertia may now be calculated.

$$I=\frac{12\times1{\cdot}17^3}{4}+2{\cdot}6\ (1{\cdot}17-0{\cdot}39)^2+4{\cdot}92\ (3{\cdot}25-1{\cdot}17)^2$$

$$I=6{\cdot}404+1{\cdot}581+21{\cdot}284=29{\cdot}269$$

from which $\frac{B}{I}=\frac{15000}{29{\cdot}269}=512{\cdot}5$

$$c=\frac{Bn}{I}=512{\cdot}5\times1{\cdot}17=599{\cdot}63 \text{ lb. per sq. in.}$$

$$t=\frac{B}{I}\ (d-n)\times15=512{\cdot}5\times2{\cdot}08\times15=15{,}990 \text{ lb. per sq. in.}$$

Remark. The minimum value of d is that which corresponds with $A_c=A_t$ (symmetrical reinforcement).

Symmetrical Reinforcement.—Symmetrical reinforcement of slabs is recommended in certain cases; for example, that of a vertical partition alternately loaded from the one side and the other. A simple solution consists in calculating d from the load on one side and then doubling the thickness, that is to say, taking $d_s=2d$ placing a single reinforcing rod in the median plane of the partition, but in this case the thickness of the partition should not exceed 3 in.

Another, and more economical, method consists in reducing the thickness which would be necessary for reinforcement in tension if reinforcement in compression were absent; this reduction is effected by means of the coefficient $\phi=0{\cdot}79$, or $d^1=0{\cdot}79\,d=0{\cdot}79\sqrt{\frac{M}{\beta}}$ or more accurately $d^1=\sqrt{\frac{B}{1824}}$ instead of $d=\sqrt{\frac{B}{1140}}$.

This rule follows from the reasoning given below: If Ac is to$=A_t$, we must put, from what has preceded,

$$\frac{B-\beta d^2}{\delta d}=\frac{3B}{(3=a)\ dt}$$

from which we obtain

$$d^2=\frac{B}{\beta}\left(1-\frac{3\delta}{(3-\alpha)\ t}\right)$$

The coefficient $1-\frac{3\delta}{(3-\alpha)\ t}$ may be calculated once for all for given values of m. c. and t. In the most usual case:

$$1-\frac{3\delta}{(3-a)\ t}=1-\frac{3\times\frac{2}{9}mc\ (3-a)}{3-a\ t}$$

$$\text{or } 1-\frac{2\times15\times600}{3\times16000}=1-\tfrac{3}{8}=\tfrac{5}{8}\quad\sqrt{\tfrac{5}{8}}=0{\cdot}79$$

$$\text{or better: } \frac{B}{1140}\times\tfrac{5}{8}=\frac{B}{1824}$$

$$\text{consequently } d^1=\sqrt{\frac{B}{1824.}}$$

The value of d^1 thus simply determined we put

$$A_c=A_t=\frac{B}{14080\times d^1},\ \text{(from (3))}$$

Example (4).

To design a slab, symmetrically reinforced, 8 ft. span, load (including own weight) 3 cwt.

$$B=\frac{3\times112\times8^2\times12}{10}=25{,}805 \text{ in.-lb.}$$

$$d^1=\sqrt{\frac{25805}{1824}}=3{\cdot}76 \quad d_s^1=4{\cdot}50$$

For a single reinforcement we should have had :

$$d=\sqrt{\frac{25805}{1140}}=4{\cdot}75$$

with the coefficient of reduction ϕ, $d^1=0{\cdot}79\times4{\cdot}75=3{\cdot}76$

$$n=0{\cdot}36\times3{\cdot}76=1{\cdot}3536$$

$$\frac{n}{3}=\frac{1{\cdot}3536}{3}=0{\cdot}4512$$

(not forgetting that it is at this distance that the reinforcement in compression must be placed).

$$A_c=A_t=\frac{25805}{14080\times3{\cdot}76}=0{\cdot}4874$$

$$I=\frac{12}{3}\times1{\cdot}3536^3+15\times0{\cdot}4874\left[(1{\cdot}3536-0{\cdot}4512)^2+(3{\cdot}76-1{\cdot}3536)^2\right]$$

$$I=9{\cdot}947+48{\cdot}348=58{\cdot}295$$

$$\frac{B}{I}=\frac{25805}{58{\cdot}295}=442{\cdot}66$$

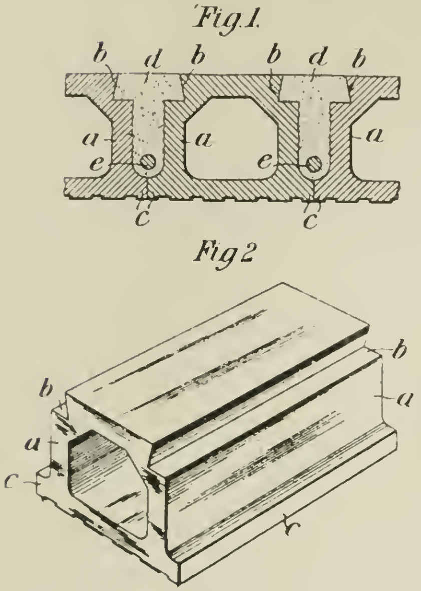
$$c=\frac{Bn}{I}=442{\cdot}66\times1{\cdot}3536=599{\cdot}20$$

$$t=\frac{B}{I}(d^1-n)\times15=442{\cdot}66\times2{\cdot}4064\times15=15{,}078$$

Remark.—It is understood that for different values of c and of t the coefficients above would have to be modified in the manner indicated.

RECENT BRITISH PATENTS RELATING TO CONCRETE.

We propose to present at intervals particulars of British Patents issued in connection with concrete and reinforced concrete. The last article appeared in our issue of August, 1916.—ED.



REINFORCED CONCRETE FLOORS.

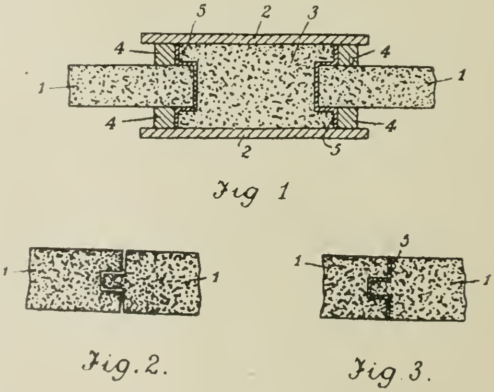
Reinforced Concrete Floors. *No.* 7941/15. *E. P. Wells*, 94, *Larkhall Rise, Clapham, London, S.W. Accepted December* 23/15.—This invention comprises an improved construction of reinforced concrete of the type which is built up of hollow bricks or tiles placed side by side with a T-shaped space between them, the space being filled with concrete in which suitable reinforcement is placed.

The blocks (*a*) are formed with undercut grooves (*b*) and flanges (*c*) at the bottom, the effect of which is to leave a space which, when filled with concrete and a reinforcing bar (*e*), form T beams, the tops of which are flush with the top surfaces of the hollow bricks.

Floors constructed as above do not require a top layer of concrete, and the floor boards can be nailed into the upper surface of the bricks. Top reinforcement may be provided in the concrete where desirable.

Concrete Walls.—*No.* 100723. *W. Calway*, 1, *Hartington Park, Redland, Bristol. Accepted June* 15/16.—For concrete walls which are cast *in situ* provision is made for ordinary expansion and contraction in accordance with this invention in the following manner. The successive portions of the wall are formed with tongue and groove joints, with their contiguous edges separated by strips, which are removed when the joints have been made and rammed.

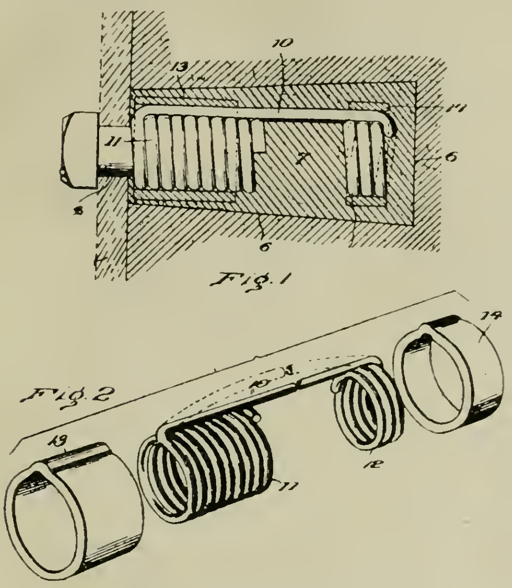
When the joints come at the junction of a pier and slabs (*Fig.* 1), the slabs (1) are first cast, separated by a gap of the requisite width. Shuttering (2 and 4) is then provided, and strips (5) of iron or other suitable material are then placed in the positions shown, and the moulds are filled with concrete and rammed, the strips (5) being removed when the concrete has set sufficiently.



CONCRETE WALLS.

When no piers occur in the wall, as in *Figs.* 2 and 3, the strips (5) are inserted when successive lengths of the wall are cast, and then removed when the concrete has set.

Metal Sockets, etc., for Concrete Structures.—*No.* 8887/15. *G. S. Mumford,* 1328, *Broadway, New York, U.S.A. Accepted June* 8/16.—Sockets for the reception of bolts and other threaded members for supporting hangers, brackets, etc., in concrete structures are formed in accordance with this invention of a body portion with an anchorage means at one end and a helical coil for the reception of the screw at the other, the body being connected to the helix at the outer end. The invention is applicable to the tie-member for spacing apart the mould members employed in accordance with Patent Specification No. 874/15.



Metal Sockets, etc., for Concrete Structures.

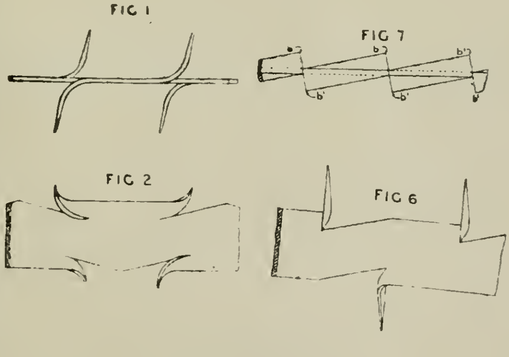
The body (10) is arched at the centre, as shown in dotted lines, for resilience, and the anchor portion (12) and socket portion (11) are formed as helices integral with the body, the coils being in opposite directions, when viewed from the same end, so that right-handed bolts may be engaged from each end. The socket is preferably longer than the anchor. The body (10) extends, as shown, to the extreme end of each helix; this construction having the effect of putting each helix in compression when a pull is exerted upon the bolt which is supported by the socket.

The sockets may be put in place during the casting of the wall, but generally they are inserted afterwards when their requisite position can be more accurately determined. An under-cut wedge-shaped recess (6) is formed in the wall and is partially filled with a soft concrete mixture, the anchor being then pressed in firmly to the required depth. To prevent the concrete from filling the interior of the socket a bolt (8) is placed in position.

Metal collars (13, 14) may be provided at one or both ends to fit snugly over the helices; these collars have an interlocking action on the helices, while the concrete is setting, and prevent them from springing and thus allowing the bolts to slip the threads.

Reinforcing Strips. — *No.* 10298/15. *C. H. J. Clayton,* 53, *Calton Road, Dulwich, London, S.E. Accepted February* 24/16.—Barbed strip metal suitable for reinforcing concrete and other purposes is formed in accordance with this invention by cutting into the edges of ordinary strip metal and bending up the freed portions.

Figs. 1 and 2 show one form, while modifications are shown in *Figs.* 6 and 7. The latter form is obtained by making staggered transverse slits partly across the strips and bending up and down respectively the two triangular portions thus left at each side between the slits.



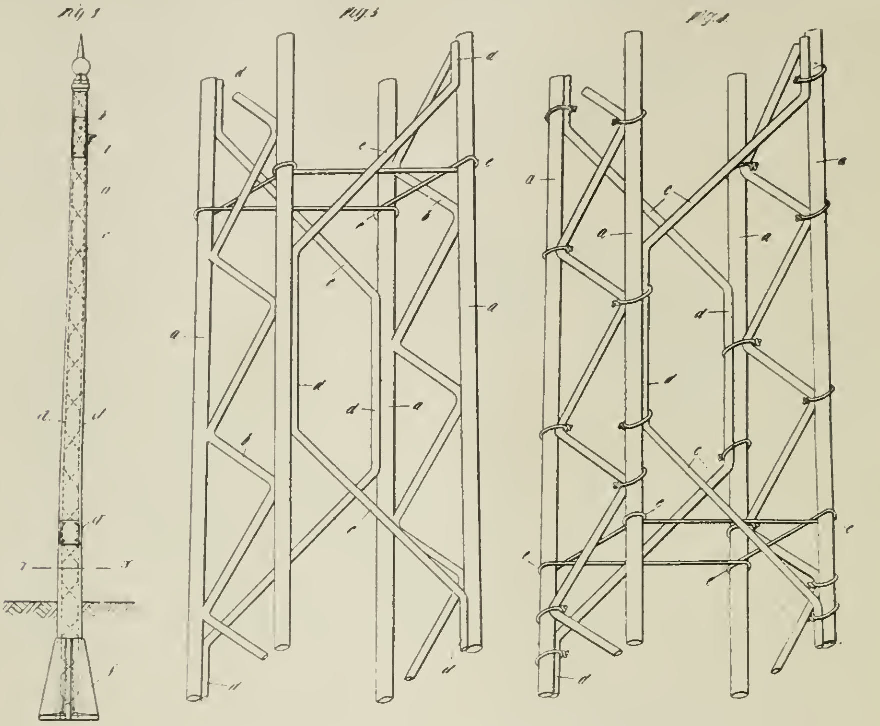
Reinforcing Strips.

Reinforcement for Concrete Columns, Posts, etc.—*No.* 13194/15. *W. Marriott, The Grange, Brinton, Melton Constable, Norfolk. Accepted September* 15/16.—According to this invention, a metal reinforcement, which is particularly applicable to columns, piles, poles, and railway signal posts, comprises rods having bracings between them, so arranged that they form with the rods a series of reversed triangles on two opposite sides and angularly disposed ties on the other two opposite sides.

Fig. 3 shows a welded and *Fig.* 4 a tied reinforcement.

The main reinforcing bars (*a*) are preferably of round section, and are arranged as usual, approximately parallel to each other at the corners of the post or column.

The bracing (*b*) on two opposite sides is made of zigzag form, secured at the angles to the bars (*a*); the bracing (*c*) on the other two opposite sides is made of a single member, having staggered straight portions (*d*) on opposite sides, the straight portions being secured to the main bars (*a*). The resulting angular ties are so arranged that they are reversely angled and that the opposite ties overlap, as shown in *Fig.* 1.



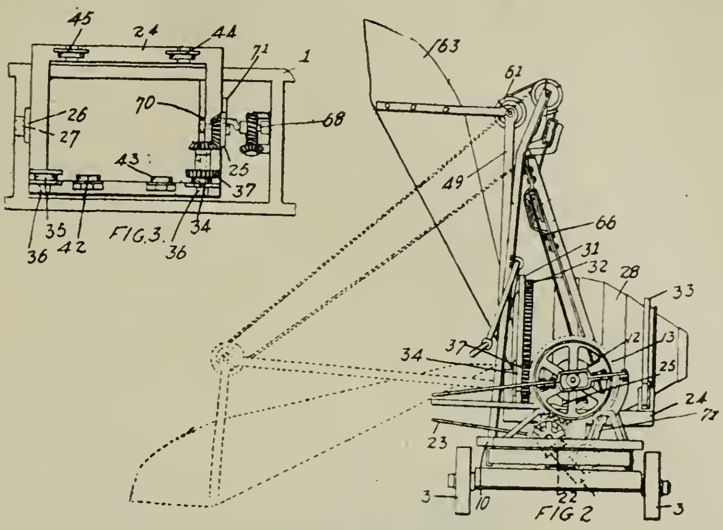
Reinforcement for Concrete Columns, Posts, etc.

The resulting reinforced concrete signal post is provided with a detachable base plate (*f*) and detachable brackets (*g*, *h*, *i*) for the balance weight, signal arm, and lamp respectively.

Concrete Mixers.—*No.* 9108/15. *W. L. Wettlaufer,* 180, *Spadina Avenue, Toronto, Canada. Accepted June* 15/16.—This invention comprises an improved form of concrete mixer of the type in which the mixing drum is tilted by worm gearing to discharge the mixture, and a delivery scoop is provided which normally rests upon the ground, and is raised by pulley tackle to deliver the materials into the mixing drum.

The machine is mounted upon wheels (3), and the various parts are driven from a motor mounted upon a platform (10). The mixing drum (28) is driven through an annular gear (32) near the delivery end by a pinion (37) mounted upon a roller (34) which supports a flange (31) on the drum, the other roller (35) for this flange being freely mounted; another flange (33) on the drum rests upon rollers (44, 45). The drum-supporting frame (24) is tilted by means of a link (71) from a crank-shaft (68) carried by a shaft which is driven in either direction by worm gearing through a bevel-gear reversing drive controlled by a lever (23).

The delivery chute (63) is carried by a pivoted arm (49), and is raised from the position shown in dotted lines by means of a rope which passes over a number of pulleys, and is carried at one end by a windlass (12); the latter is carried upon an extension of the motor shaft, and is controlled by a clutch. The chute (63) is returned by gravity when the clutch is thrown out, and is governed in its downward movement by a brake mechanism formed integrally with the windlass (12).



Concrete Mixers.

The supporting frame (24) for the drum is pivotally supported at one end by a lug (26) engaging a stud (27), carried upon a standard secured to the main frame of the machine, and at the other end by a lug (25) engaging the main motor shaft.

NEW WORKS IN CONCRETE

AT HOME AND ABROAD.

Under this heading reliable information will be presented of new works in course of construction or completed, and the examples selected will be from all parts of the world. It is not the intention to describe these works in detail, but rather to indicate their existence and illustrate their primary features, at the most explaining the idea which served as a basis for the design.—ED.

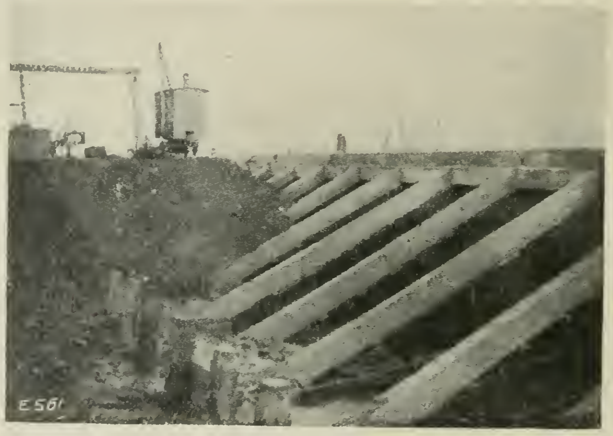
QUAY WALL AND FOUNDATIONS ON THE THAMES AT SILVERTOWN.

A LARGE number of piles and sheet piles on the "Coignet System" have recently been used for the construction of an extensive quay wall and the foundations of some new buildings on the Thames at Silvertown for Messrs. Loders and Nucoline, at Cairn Mills.

These important additions to the existing premises have been occasioned by the very extensive development of this particular class of business, which consists in the manufacture and refining of nut oil.

The whole of this reinforced concrete work was carried out under the general supervision and in accordance with the requirements of Mr. Bruce Dawson, F.R.I.B.A., architect. The structure was carried out in two portions, the first contract being for a quay wall facing the river of a total length of 75 ft., with a return wall having a total length of 135 ft., this side being used principally as a barge berth.

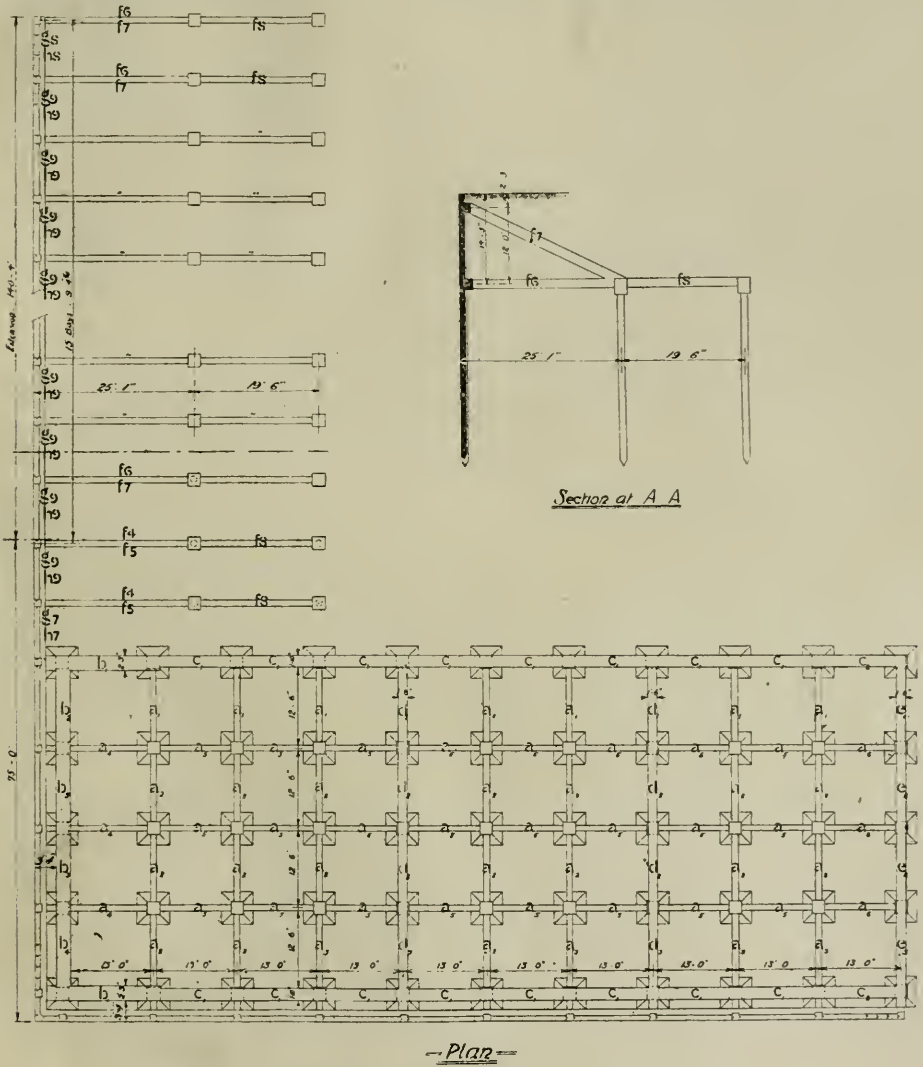
The foundations of the future building run parallel to this side of the wharf, having the same length, and for a width of about 55 ft. These foundations are composed of fifty-five groups of piles, 14 in. in diameter and octagonal in shape, each group being formed of four piles 40 ft. long. These reinforced concrete piles were constructed in accordance with the usual Coignet principle, namely, by preparing beforehand a steel frame composed of about fourteen bars of small diameter, surrounded at intervals by wire hoops. This reinforcement is then suspended in a timber mould and concreted horizontally on the ground. After six or seven weeks, when the piles were sufficiently matured, they were lifted in position by means of a crane and driven by means of a Sykes driving apparatus. Each group of piles was surmounted by a cap in the shape of a pyramid, and reinforced in such a manner as to distribute the loads equally over the four piles.



QUAY WALL AND FOUNDATIONS, NEW WHARF, CAIRN MILLS, SILVERTOWN.

The wharf front or quay wall was composed of sheet piles, 10 in. thick and about 18 in. wide, with a length of 40 ft. These piles were reinforced by means of eight bars of small diameter, tied together by hoops and arranged in the form of a rectangle. The sheet piles were made in a similar manner to the octagonal piles. At intervals 13 ft. centres king piles were provided, in order to stiffen the quay wall and so as to form a suitable connection to the reinforced concrete land ties. The king piles are square, with scantlings of 14 in. by 14 in. Both the sheet piles and the king piles were moulded with tongue and groove.

The piles and sheet piles were driven first after a certain number of old timber piles had been extracted from the ground by means of an ingenious extracting apparatus based on the principle of leverage, an existing timber pile being used in succession as a fulcrum for lifting the adjoining piles. The foundation piles were then driven and the land ties and connecting beams were placed in position and concreted in the final operations. It was necessary, owing to the very unstable quality of the ground, which is mainly composed of mud to a very great depth, to strongly tie back the quay wall by means of reinforced concrete land ties fixed to the groups of piles forming the foundations of the future building. The piles and sheet piles forming the wharf were made sufficiently long to penetrate a few feet into the bed of gravel,



Quay Wall and Foundations, New Wharf, Cairn Mills, Silvertown.

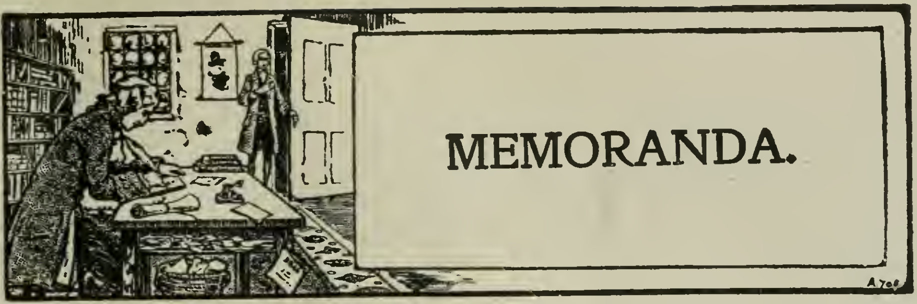
which is situated at a distance varying between 35 and 40 ft. from the actual finished level of the ground. Heavy reinforced concrete beams have been provided to connect the foundation caps and to support the walls of the future building and distribute the weight of the latter on to the foundations in a uniform manner. The reinforcement of these beams was composed of a certain number of straight bars at the top and bottom of each beam, these bars being connected by wire stirrups, spaced at suitable intervals to counteract shearing efforts. Each set of top and bottom bars, with its stirrups, was prepared beforehand, and wired together in order to form an independent unit, which could be placed in position in the moulds and concreted without fear of any of the bars getting out of their respective positions.

The second contract was for the extension of the wharf front, facing the river, and to a length of about 140 ft. The quay wall was constructed in a similar manner as previously described, by means of piles and sheet piles securely tied back by horizontal and inclined reinforced concrete land ties, fixed to the top of two consecutive reinforced concrete octagonal piles driven to a suitable level.

As soon as the reinforced concrete work was sufficiently hard to take the required loads, the earth filling was gradually placed in position at the back of the work, and a certain number of timber fender piles were driven in front of the quay wall to protect the concrete from being damaged by the bumping of barges and steamers coming alongside.

The accompanying photograph shows the back of the quay wall, with the reinforced concrete land ties during the filling in of the earth.

The whole of the work was carried out by Messrs. Anthony Fasey and Son, contractors, of Grove Green Yard, Leytonstone, and the reinforced concrete plans were prepared by Messrs. Edmond Coignet, Ltd., of 20, Victoria Street, Westminster.



MEMORANDA.

Memoranda and News Items are presented under this heading, with occasional editorial comment. Authentic news will be welcome.—ED.

British Prisoners of War Book Scheme.—The Board of Education have issued a first list of classified books urgently needed to meet the requests of British prisoners of war, and among the lists given appeal is also made for the following:—

"Engineers' Handbook" (Adams).
"Reinforced Concrete Construction."
"Structural Engineering (Elementary)."

If any of our readers are able to meet these needs, or any one of them, will they please communicate in the first instance, before sending the books, with Alfred T. Davies, Esq., J.P., Board of Education, Whitehall, S.W., giving particulars as to date of edition, number of copies available, and author.

Concrete Institute.—On Thursday, December 21st, Prof. Henry Adams, M.Inst.C.E., will read a paper on "Pile Driving and the Supporting Power of Piles." The meeting will take place at 5.30 p.m. at Denison House, Vauxhall Bridge Road, S.W.

Hull.—Large Reinforced Concrete Stores.—Messrs. Hammond's new stores in Hull were opened quite recently. The building is a large and imposing block, and has been erected on an island site. The structure is steel frame protected by concrete, and all the floors and roof are of concrete construction. The premises provide a floor area of over three acres.

A New Niagara Bridge.—The Ontario and Niagara Connecting Bridge Company is to build a bridge of steel and concrete over the Niagara at Niagara Falls. The bridge is to be available for steam and electric railways, vehicles, and pedestrians; its cost is estimated at £200,000. The structure will span the Niagara near a point at which the transmission line of the Niagara, Lockport, and Ontario Power Company crosses the rapids.

Concrete Covering for Ironwork.—In connection with the enlargement of the Victoria terminus of the London, Brighton and South Coast Railway a covering of nearly pure concrete to all the overbridges in the station has been adopted. The ironwork is thus protected from corrosion from the weather, and from the steam emitted by the locomotives in passing under. At the Cortlandt Street ferry end of the Pennsylvania and New York City Railway the whole of the steel work has been covered with a thin coating of sand and cement sprayed on it by means of a "cement gun" after carefully cleansing the surfaces of the steel work. A test piece successfully resisted most severe trials. It was kept in moist salt air for three days, in salt water for three days, in a temperature of 5 deg. below zero for forty-eight hours, and then allowed to thaw in a warm room; then it was placed on top of a boiler subjected to a heat of 110 deg. for three days; then it was dropped 2 ft. on a wooden floor, again on a concrete one, and showed no signs of cracking.—*Engineer.*

A Novel Method of Trapping Gas from Oil Well.—*The Dome of Concrete over Potrero No. 4, Mexico, and How it is Used.*—In a recent issue of *The Petroleum World* the following interesting particulars were published:—

"The Mexican Eagle Oil Company's well No. 4, Potrero del Llano, has had a

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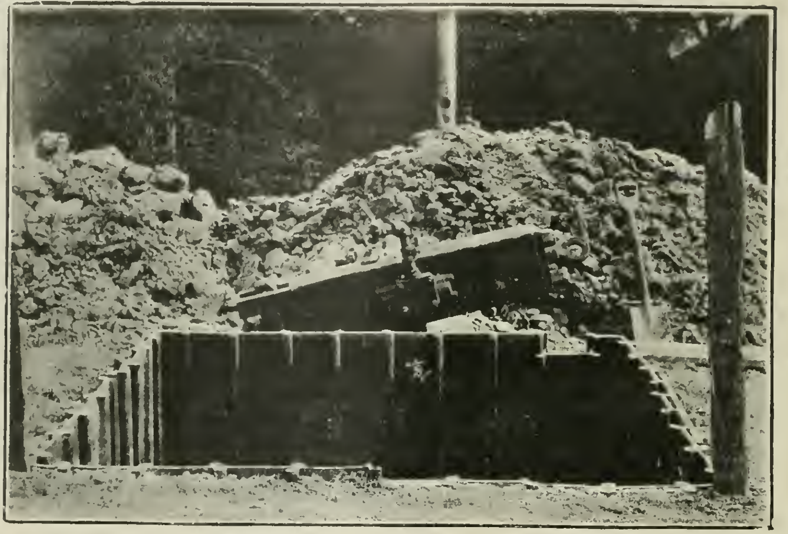

The above photograph needs no explanation. It shows the 8 in. wide " SIMPLEX " Steel Sheet Piling and the DOUBLE-ACTING (McKiernan-Terry Patent) HAMMER with which it was driven. The shaft is symmetrical and the job clean.

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more eventful history than perhaps any other oil well in the world. It was brought in in December, 1910, at the rate of 120,000 barrels a day, and was then the world's largest well. It has been held in since to a fraction of its capacity. During the Mexican disturbances of three or four years ago, when some wells suffered damage, a concrete building looking much like a large tomb or small chapel, was erected over the well, which thus escaped injury, the oil flowing (partly held in) all the time. In fact, the well has never ceased to flow and is flowing now. In 1914, on August 14th, the well caught fire, the most troublesome feature of the outbreak being the gas seepages from cracks that had formed in the soil and round about the casing. The fire was fought with a battery of boilers which discharged steam upon the flames; but, though it was got under control, several months elapsed before it was finally put out by the use of earth.

"After the fire, gas still continued to escape from numerous seepages round the well head. It was therefore determined to build a *concrete* dome or mound, covering nearly all these gas seepages, the idea being that the gas would escape from the seepages into the interior of the concrete dome, and thence through pipes, under its own pressure, to a point some distance away, where it would be burned in flares. This idea was carried out. The rock pressure of the gas, which is from 600 to 800 lb. per sq. in. (a rather large pressure compared with the average) easily drives it into the various pipes, which have ends open into the dome, and the same pressure drives it along the pipes to the place of consumption. The quantity is very large, and is said to be variable."

Potash from Cement.—In a review of the developments in the potash industry in the United States in 1915, issued by the United States Geological Survey, it is stated that potash was recovered, as a by-product, last year, from the manufacture of Portland cement at Riverside, California. By-product potash from this source has already yielded a considerable revenue.

Concrete Roads.—Of one system for 166 miles of improved roads in Vermillion County, Illinois, 145 miles will be concrete.

Improvements at Sydney Harbour.—Under its scheme of port improvement the Sydney Harbour Trust is carrying out several important works, including the building of two jetties. The eastern jetty consists of a reinforced concrete wharf, built round three sides of the reclamation area. The total width of the top is 259 ft. and the length of the sides 1,124 ft. and 838 ft. respectively. In regard to the wharf, the piles are sheathed with reinforced concrete cylinders down to about 6 ft. below the profile of the ballast bank of the reclamation area. At the back of the wharf a reinforced concrete trestle retaining wall holds back the filling from above low water mark.

South Africa.—Further particulars of the proposed scheme for supplying the Witwatersrand with water are forthcoming. The modified scheme provides for the erection at Lindeque of a barrage composed of thirty-six gates, each 25 ft. high and 30 ft. wide. It will impound altogether 13,633,000,000 gallons. The estimated cost of the scheme is £758,000.

Columbia.—The Columbian Government propose taking important steps to combat yellow fever at Buenaventura. They include works for protection against inundations of the sea at high tides and the construction of large reinforced cement tanks in the higher part of the town to receive rain water, which will be distributed through pipes. The tanks will be covered with wire netting.

Reinforced Concrete Electric Light Poles.—The Woodhouse and Baillie Electricity Co., which distributes electric energy for a distance of about ten miles along the Italian Riviera, is using poles of reinforced concrete for the support of transformers. Inside the pole are eight iron rods, four of which pass out at the top of the pole, and are there held by an octagonal plate, to which they are fixed by means of nuts. The plate has a central hole, through which passes the iron tube for the support of the frame carrying the insulators.

Table Bay Harbour Works.—The annual report of the general manager of the South African Harbours and Railways states that the concrete dwarf wall of the Table Bay breakwater has been advanced 516 ft. Notwithstanding the shortage of

E 2

cement, 80 per cent. of the work of reconstructing the No. 2 jetty has been completed. Good progress has been made with the erection of the reinforced concrete signal tower on the breakwater capping.

Concrete Electric Conduits.—At a recent convention in Chicago of the National Electric Light Association it was reported that concrete electric conduits are coming into extensive use. Single duct pipe is used, with the following dimensions: Length, 5 ft.; internal diameter, $3\frac{1}{2}$ in.; wall thickness, $\frac{3}{8}$ in. Split bends and straight lengths are made as specials. It was stated that cable burnouts are not communicated to other ducts, as is the case with vitrified tile conduit.

PROPOSED WORKS.

London.— The reinforced concrete work in connection with the rebuilding of 22, Birchin Lane, will be carried out by Messrs. Dove Bros., the general contractors.

Guildford—Tenders have been called for for the reconstruction of the Curzon Bridge, Pirbright, with concrete abutments.

Rotherham.—Plans have been passed by the Corporation for a reinforced concrete motor garage for Messrs. Steel, Peach and Tozer.

Blackpool.—A Bill is to be promoted by the Corporation for power to extend the sea wall at a cost of £40,000.

London.—The Main Drainage Committee of the London County Council reports that, in connection with the proposed erection of coal bunkers at the southern outfall, an agreement was entered into with Edmond Coignet, Ltd., to assist the Council with regard to the work, which would be carried out in reinforced concrete. The company had prepared several designs and estimates, and had submitted their final drawings and quantities, but, owing to the war, the erection of the bunkers had been postponed. In the circumstances the Committee had authorised the payment of a sum not exceeding 80 per cent. of the estimated amount due to the company.

Canada.—Tenders have just been invited by the Canadian Department of Railways for the construction of a reinforced concrete grain elevator with a capacity of 500,000 bushels at St. Johns, N.B.

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CONCRETE THE MONEY SAVER

CONCRETE BLOCKS AND HOW TO MAKE THEM.

(*Concluded.*)

In the following articles (which have been specially contributed), it is intended to give instructions of how to make the concrete blocks. The machinery, moulds, etc., are referred to only in a general way, as we have already illustrated and described from time to time the principal types of block-making machines, etc., that are on the market in this country.—ED.

ERECTION OF BUILDINGS WITH CONCRETE BLOCKS (*continued*).

IN building cavity walls, it is always essential to have the cavity well ventilated by air bricks, and to make perfectly certain that there is a clear and complete circulation. It is best to have another set of air bricks at the top, see *Fig.* 22. With this arrangement it is possible to have an absolutely dry inner wall. With care it is very simple to erect a building with concrete blocks of any description. When scaffolding for concrete building it is always best to erect an independent scaffold, so that there are no putlog holes to be filled in when the job is completed. It will be found that a better-looking job can be made of concrete block walling by this method of scaffolding than the ordinary method employed when bricks are used. All that is required is about double the quantity of poles.

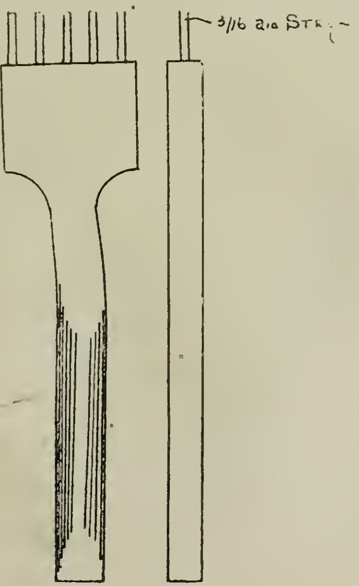


FIG. 21. SCRATCHER.

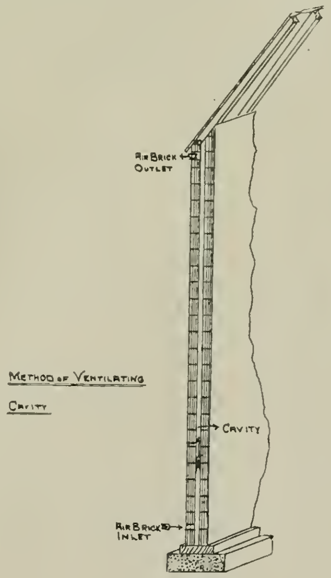


FIG. 22.

THE MAKING OF WINDOW CILLS, DOORSTEPS, HEADSTONES, etc.

Before describing how to make the actual window cills, etc., a word or two on how to make the moulds for same will perhaps be very useful to some of our readers.

Fig. 1 (p. 695) shows a view of a mould for making window cills, and it can be made by any average carpenter or joiner. *Figs.* 2 and 3 (p. 695) give the detail of the sides of the mould, which need no further elaboration. *Fig.* 4 is the piece which forms the ends of the mould, and it requires two of these to complete the mould. If shorter cills are wanted than 7 ft. 6 in. it is necessary to have sliding divisions as shown in *Fig.* 5 (p. 695), and if short cills, say, for instance, 2 ft. long, are required, it will be easily seen that by using four divisions, as shown in *Fig.* 5 (p. 695), that three cills can be made at one operation of the mould.

Fig. 6 (p. 695) shows the detail of the cramps for holding the mould together, and three of these should be used to the one mould, as this will prevent the mould from ramming out or bulging. These should be made in wrought iron.

For making window or door heads it is necessary to substitute *Fig.* 7 (p. 697) in the place of *Fig.* 3, and *Fig.* 8 (p. 697) will then be required for the ends instead of *Fig.* 4, and the divisions for the making of short heads are shown in *Fig.* 9 (p. 697). The same cramps can be utilised for heads as are used for cills.

For making plain doorsteps the sides of the mould are the same as for making heads, with different ends and divisions, which are shown in *Figs.* 10 and 11 (p. 697). It will be noticed that these allow for the making of doorsteps 3 in. thick, but the ends and divisions can be increased or decreased, as the case may be, according to the requirements. This will allow for either thicker or thinner steps as wanted. It will be noticed that *Fig.* 2 (p. 695) has a half-round piece of iron screwed to it when making cills. This forms the weathering on the under side of the cills. It requires removing for making of heads or steps. The surface of the mould should be treated with two or three coats of French polish or with shellac dissolved in methylated spirits. The top edges should be lined up with ⅛-in. iron plates, so as to protect them from the rammer and keep them from chipping.

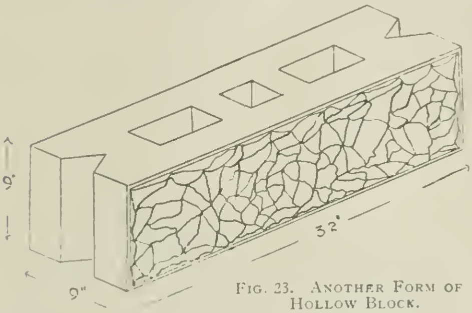


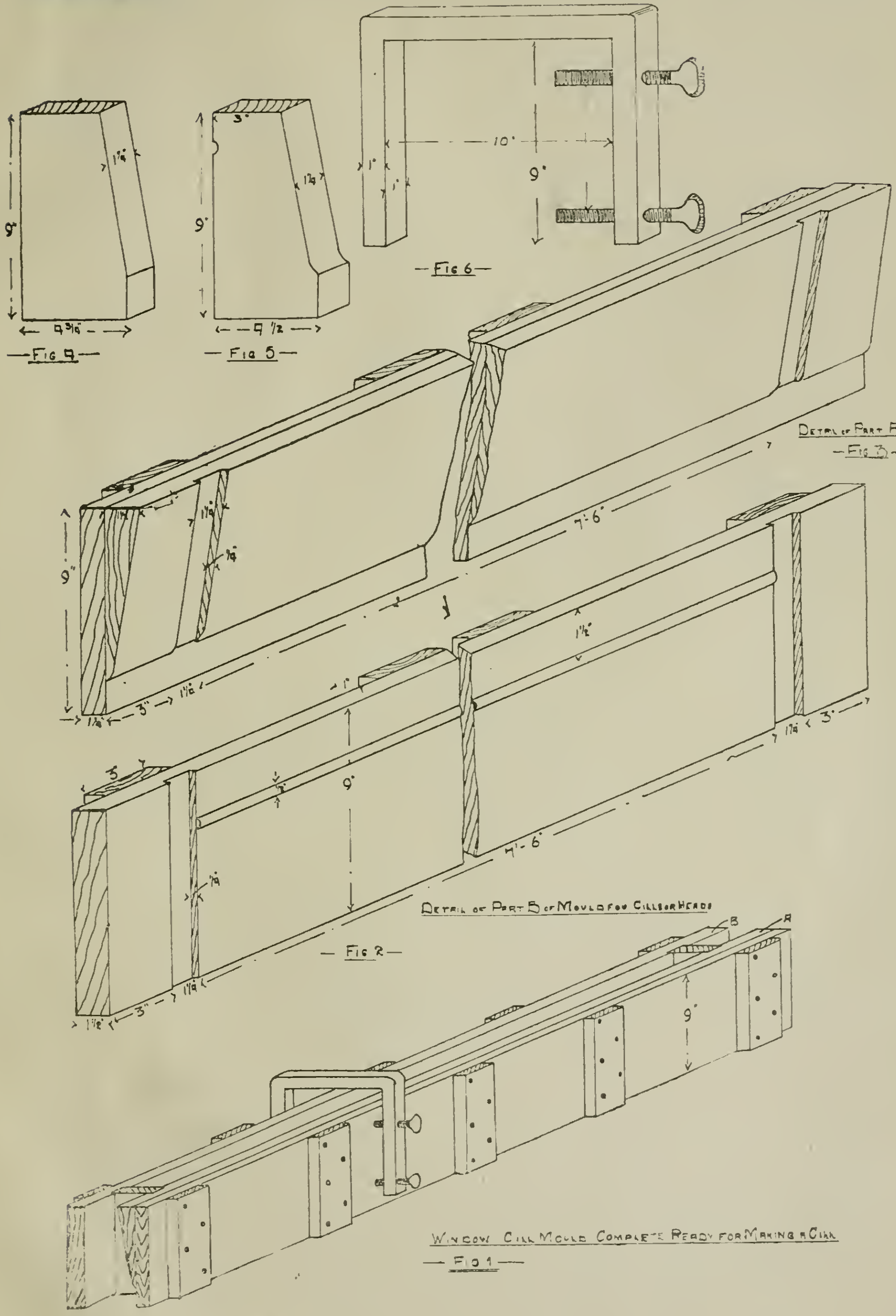
Fig. 23. Another Form of Hollow Block.

The mould should be kept quite clean, and should be occasionally rubbed with an oily rag.

All window cills, window and door heads, doorsteps, and rough lintels for the inside heads of doors, windows, and also for chimney openings, should be reinforced with iron rods or bars. The size of the bars depends upon the distance between the supports, but the writer has found from much experience and practical use that, for all window and door heads and lintels of all kinds, coke breeze is the best aggregate to use. For reinforcement, where the distance between the supports is not more than 4 ft. 6 in., two ½-in. dia. rods are large enough, but the lintel or head must have at least 6 in. of bearing each end, and, in most cases, where the heads are used with concrete blocks, 9 in. of bearing is given each end. If the opening is larger than 4 ft. 6 in. larger reinforcements will be required. If straight rods are used, the ends will require turning to prevent them drawing out of the concrete. Machines can be obtained for bending iron or steel rods to any shape for concrete work. The size of the lintel or head used for cavity block walls is 9 in. by 4½ in. usually, as this size works in with the blocks. A section is given of a head or lintel showing the position of the reinforcing, which is placed so as to obtain the best advantage from it (see p. 696). Cills and doorsteps, which are generally bedded on the walls or upon blocks or brickwork, only need reinforcing so that they can be handled with greater ease, and there is thus less liability to breakage.

An illustration is given of sections of window cills, doorsteps, and steps which are suitable for a staircase or any other purpose of the same kind. (See *Figs.* 24 and 25.)

The manufacture of window cills and heads is much on the same principle as making hand tamped blocks, but the aggregates require to be graded somewhat differently.



— Fig 4 —

— Fig 5 —

— Fig 6 —

Detail of Part A
— Fig 3 —

Detail of Part B of Mould for Cills or Heads
— Fig 2 —

Window Cill Mould Complete Ready for Making a Cill
— Fig 1 —

The Making of Window Cills, Doorsteps, Headstones, etc

In many cases good clean shingle or breeze is used for the inside mixture of cills or heads, and this is gauged three of ½-in. to ⅛-in. breeze or shingle to one of washed sand, and one of cement. These mixtures are only wetted to a semi-dry consistency, as mentioned for making blocks, and the facing is put around the sides and face of the mould; the coarser mixture is filled in upon it, and all tamped down together. Before putting any more material into the mould the surface of the concrete must be scratched so as to ensure one layer adhering to the other. The reinforcing iron should be given a coat of cement wash before inserting in the concrete. This gives a key between the iron or steel rods and the concrete.

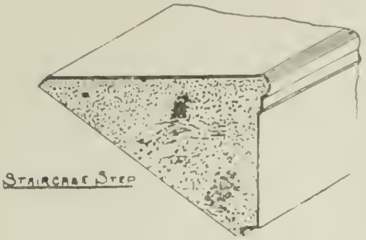


Fig. 24.

Doorsteps can be made in two ways, *i.e.*, upon a floor with the face or wearing surface upwards, or with the face down, which means turning the mould over after finishing the step, and leaving the face upwards to dry off. But the most common way is the "face up" method, as a harder and more dense surface can be obtained. It is well to give steps a coat of cement wash all over after they have been made a week or ten days. If the "face up" method is adopted, after striking the material off level with the top of the mould, a little water can be applied to the surface, and the face then finished off with a plasterer's trowel. This gives the wearing face a good hard surface. The aggregates for doorsteps and the like are gauged with one and a half of fine granite chippings, one of washed sand to one of cement. This is for the facing, which should be ½ in. to ¾ in. in thickness. The coarser material for the inside should be composed of two and a half shingle from ½ in. to ⅛ in. to one of washed sand to one of cement. In all cases the mixtures are only wetted sufficiently to compose a semi-dry mixture as before described in connection with blocks. After heads, lintels, cills, or doorsteps have been made twenty-four hours, a sprinkling of water must be applied, and this watering must be continued for each day for six or eight days. It is always well to remember that water is cheaper than cement. By this is meant that, if an article were made with three of aggregate to one of cement and left to dry without any water being applied to it after being made and during the hardening process, it would be found that if

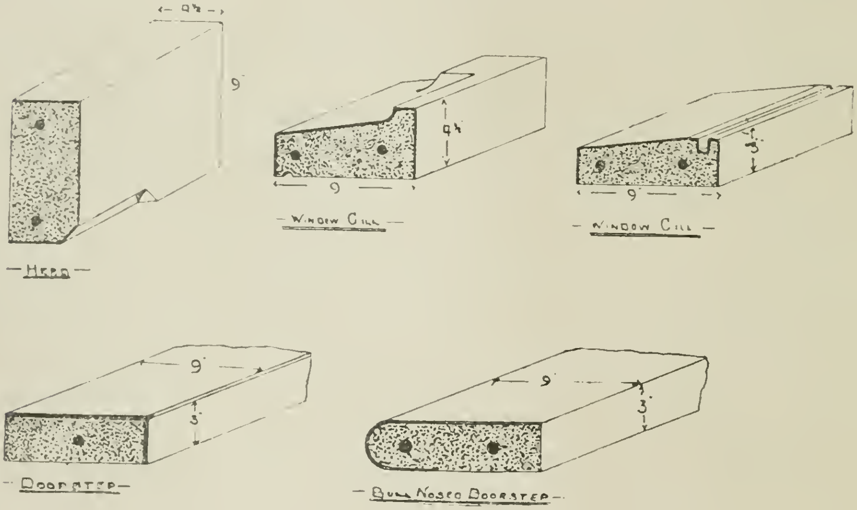
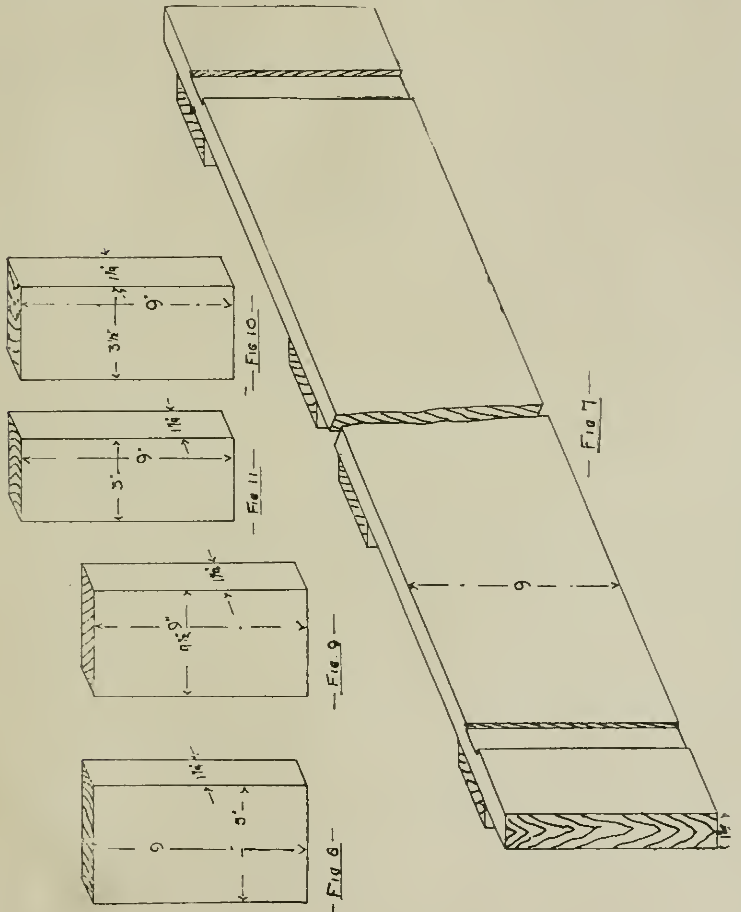


Fig. 25.

the same article were made on exactly the same principle but gauged six of aggregate to one of cement, and after it had been made twenty-four hours water was sprinkled upon it for six days; after two months the six to one article would be stronger than the one gauged three to one. Hence, water is cheaper than cement. It is always a good plan to give the articles a good watering after putting into stacks, as this gives them a further chance of gradually hardening off.

CONCRETE FOR GARDEN EDGING.

Concrete is now being used in many different forms as edging for gardens, etc. In some cases it is made *in situ*, while in others it is used in the form of special shaped concrete blocks, but the most ornamental and artistic form is when it takes the form of coloured garden edging tiles.



— Fig 7 —

— Fig 10 —

— Fig 11 —

— Fig 9 —

— Fig 8 —

The Making of Headstones and Doorsteps.

When done *in situ*, boards are necessary to hold the concrete in position and shape until it has set. Practically any shape can be adopted for the top, but *Fig.* 1 (p. 699) shows a set of boards complete, ready to be placed in position to receive the concrete. These boards are held together by means of bolts and fly-nuts, and where each bolt is, a piece of iron tubing is placed so that the bolt may pass through it. By using these tubes it is possible to tighten the boards up so that they are perfectly rigid. It must be noted that the length of the tube is the thickness of the concrete. When the concrete has set enough to allow the boards to be taken away, the pieces of tubing can be taken out with care and used again. The holes made by the tubes can be filled up with a mixture of sand and cement.

The thickness of this type of edging depends upon its position, such as whether it is used as an edging to a garden bordering, a carriage drive, or for an ordinary garden path, etc. If used for a carriage drive it naturally requires to be thicker than one for a garden path, but 2 in. should be ample thickness for all ordinary purposes. *Fig.* 2 (p. 699) is an alternative method of constructing the boards. *Fig.* 3 (p. 699) gives a view of a piece of garden edging made in between these boards, and it shows how an extra leg can be made if necessary every five or six feet, so as to make the edging perfectly secure in the ground. If an extra leg is needed, all that is necessary is to make a rough hole in the soil four or six inches deeper than the bottom of the edging, and when filling in between the boards with concrete make sure that holes in the soil are also filled. The mixture for making garden edging of this type should be 3 of shingle (which will pass a $\frac{3}{4}$-in. sieve and be retained on a $\frac{1}{4}$-in. sieve), 3 of sharp sand, to 1 of cement. It should be mixed fairly wet.

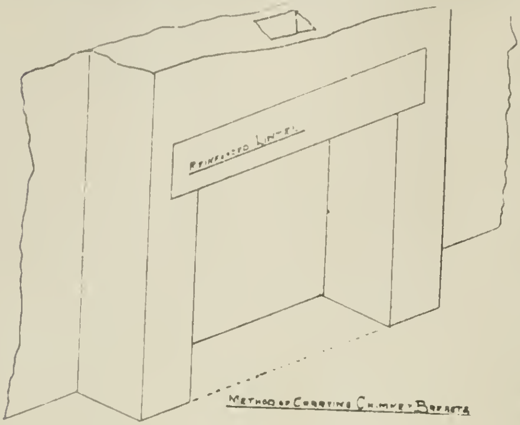


FIG. 26.

Fig. 4 (p. 699) shows another type of edging, which is now largely used by the G.E. Railway Co. for edging to the flower borders upon their stations. It is an ordinary concrete block which has the top edges rounded off. This is a very simple, cheap, and yet very efficient form of edging, and could be made in the mould described in our October and November issues with a few simple additions to form the rounded edges, and could be made to any depth, thickness, or length which may be required.

We will now take the ornamental types of garden edging which are made in the form of tiles, and there are some very nice designs now upon the market, such as shell pattern, shamrock pattern, and many others. The moulds for these can be made of iron, wood, or plaster according to the number of tiles required. If a plaster mould is required, the operation for making it is very similar to the one described in our August issue with reference to making a plaster mould for balustrading, but is much more simple, as the back of most garden edge tiles is flat. The operation for making the mould is as follows: Having obtained the pattern of the tile which it is proposed to make (this pattern may be in wood, plaster, or terra-cotta, etc.), a box without top or bottom is made, allowing the box so much larger and deeper than the pattern, so as to give the mould sufficient strength to withstand the wear and jars when it is in use. Next, place the pattern upon a flat surface, after having well oiled it, then place the box around it and pour in the plaster. When set,

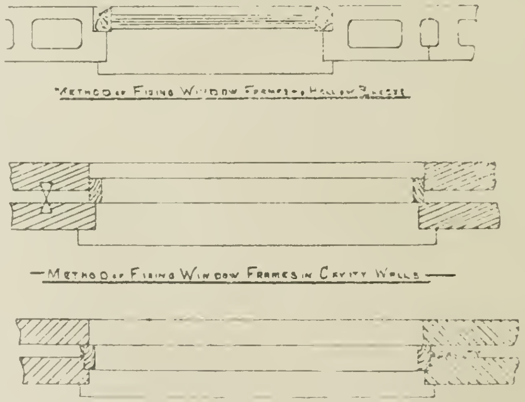

Method of Fixing Window Frames in Hollow Blocks
— Method of Fixing Window Frames in Cavity Walls —

FIG. 27.

CONCRETE FOR GARDEN EDGING.

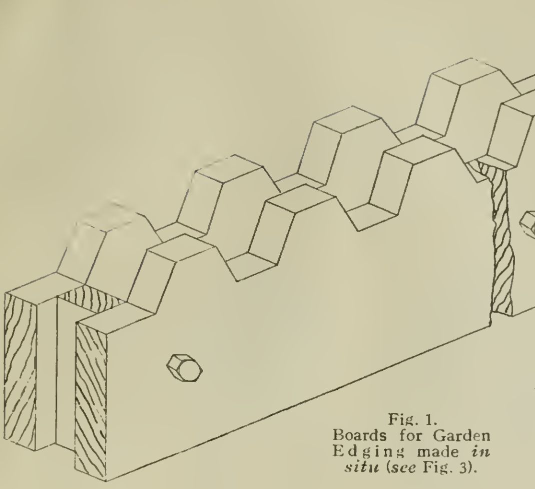
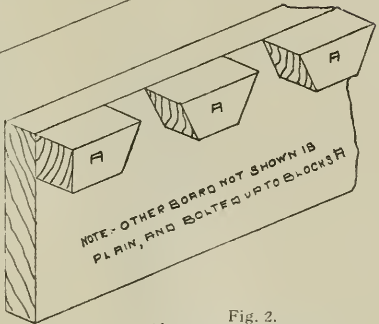


Fig. 1. Boards for Garden Edging made *in situ* (*see* Fig. 3).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NOTE.- OTHER BOARD NOT SHOWN IS PLAIN, AND BOLTED UP TO BLOCKS A

Fig. 2. Alternative method of making Boards (concrete is filled between blocks A and well rammed).

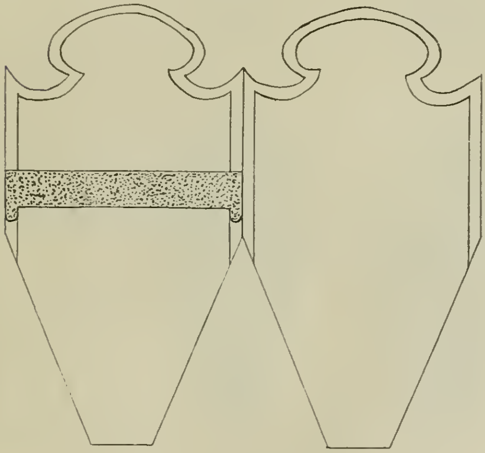

Fig. 5. Coloured Edging Tiles.

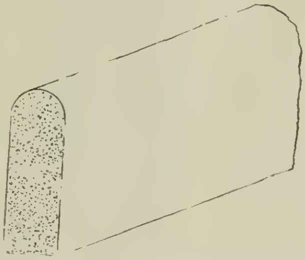

Fig. 4. Concrete Block Edging.

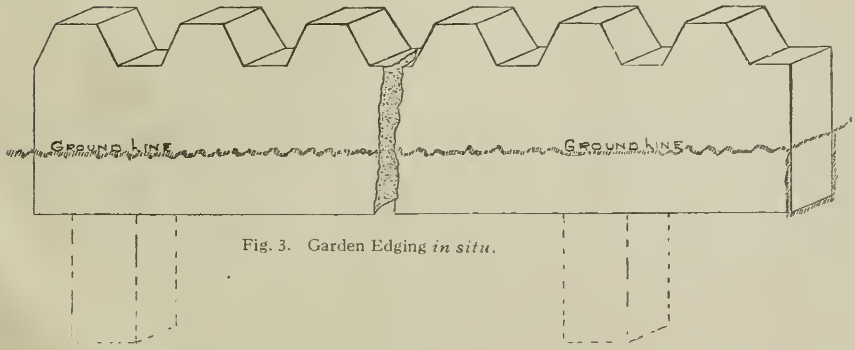

Fig. 3. Garden Edging *in situ*.

remove the mould (as it is now) from the flat surface, and turn it over and take out pattern. Leave it for three or four days to dry off, and then give it a coat of shellac varnish, and it is then ready for use. Of course, wood or iron moulds are more serviceable than plaster.

The mixture for making the tiles referred to above should be 3 of clean sharp sand to 1 of cement. If coloured edging is required, the sand should be mixed with the colour before adding the cement. A definite proportion for the colour cannot be given, as it depends upon the colour itself, the tint the tile is required, and the colour of the sand, but practically any coloured tile can be made. The mixture should not be made too wet, or the tile will lose its shape when it is turned out of the mould. The mixture, when mixed, is tamped into the mould, and the back of tile (which is the top of the mould) is levelled and smoothed off with a trowel, and a piece of board or metal is then placed upon it, and the whole is turned over on to a bench. The board or metal is left lying upon the bench, and the mould is lifted up with care. It will be found that the tile is left lying upon the piece of board or metal, and the mould is then ready for use again. With practice it is possible to make several hundreds of these in one day. After they have been made twelve hours they should be well watered, and when they have had three days to harden they can be placed in stacks to finish hardening off. *Fig.* 5a shows some different designs of coloured garden edgings which are being made in this country. It is essential to protect these from the frost in winter and sun and draughts in summer for at least a week after making.

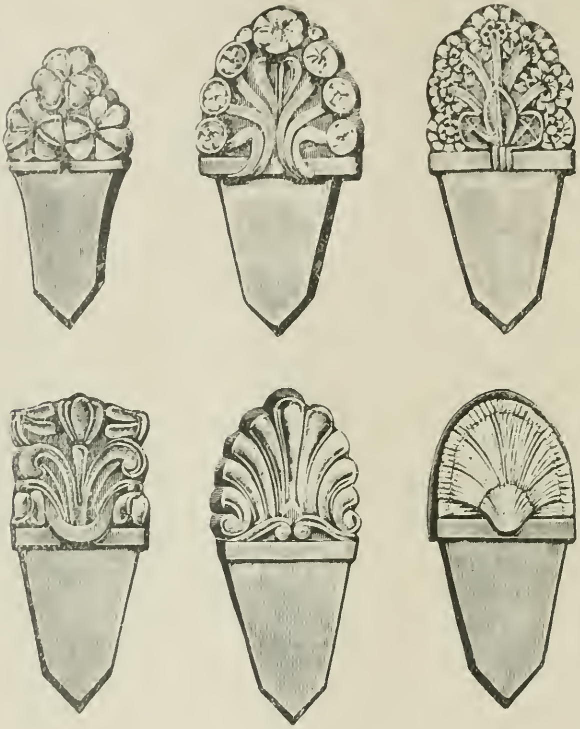

Fig. 5a. Coloured Edging Tiles.

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